A PRACTICAL TREATISE

ON THE

CONSTRUCTION AND FORMATION

OF

RAILWAYS.

Entered at Stationers Hall.

A PRACTICAL TREATISE

ON THE

CONSTRUCTION AND FORMATION

OF

RAILWAYS,

CONTAINING

THE MOST APPROVED SYSTEMS OF

EXCAVATING, HAULAGE, EMBANKING,
PERMANENT WAYLAYING, &c. &c.

ALSO, THE METHOD OF ESTIMATING

THE GROSS LOAD AND USEFUL EFFECT PRODUCED BY MECHANICAL
OR OTHER MOTIVE POWER UPON A LEVEL,
AND UPON ANY INCLINATION;

ILLUSTRATED WITH

DIAGRAMS AND ORIGINAL USEFUL TABLES.

TO WHICH IS ADDED,

COMPREHENSIVE EARTHWORK TABLES.

BY JAS. DAY,

AUTHOR OF THE RAILWAY CALCULATOR, OR ENGINEERS' AND
CONTRACTORS' ASSISTANT, &c. &c.

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TO

JOSEPH LOCKE, ESQ. M.P., F.R.S.,

AND

J. E. ERRINGTON, ESQ., M. Inst. C. E.,

THIS WORK IS,

WITH THEIR KIND PERMISSION,

RESPECTFULLY

DEDICATED,

BY THEIR MOST OBEDIENT SERVANT,

THE AUTHOR.

PREFACE.

THE object of this Work is to give a practical exposition of that now popular and all-important subject, RAILWAYS, a medium of internal communication which has been brought so rapidly forward to its present comparative state of perfection by the united efforts of the British nation.

The Work has been arranged in the following order: — INTERNAL COMMUNICATION, GRADIENTS, EXCAVATING, HAULAGE, EMBANKING, BRIDGES AND CULVERTS, FENCING, PERMANENT WAYLAYING, and EARTHWORK TABLES, each subject forming a chapter of itself. The Author has thus endeavoured to treat separately of the several kinds of works, their nature, material, stages, processes, &c. &c., in order to render each subject distinct, clear, and comprehensive.

The Tables, it is hoped, will be of great utility, not only as a medium of general reference, but also of abridging tedious calculations. It was deemed advisable to give copious examples illustrating their

use, likewise in some instances the method by which they had been calculated, in order that any person might understand their principle, and those conversant with the subject see immediately how the results had been obtained.

In the EARTHWORK TABLES an additional column of eighteen feet has been inserted, which will be found very useful for calculating the contents of single lines of railway, road diversions, &c.; the breadths at the Formation-Level now being 18, 24, 27, 30, 33, and 36 feet respectively. The tables have also been considerably extended, namely, those of 1 and $1\frac{1}{4}$ to 1, from forty to seventy feet in depth; those of $1\frac{1}{2}$ and $1\frac{3}{4}$ to 1, from fifty-four to seventy feet in depth; and the 2 to 1 table has been extended from seventy to one hundred feet in depth. The Tables increase regularly in depth *three inches* each time, so that any depth of cutting or embankment (within the above limits) may be found within *one and a half* inches of the required depth.

The greatest attention has been bestowed in preparing the several Tables for the press and in the revision of the proof-sheets, and the Author confidently expects that no errors have been overlooked.

Borrow Bridge, Kendal,
August, 1848.

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A

PRACTICAL TREATISE

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RAILWAYS.

CHAPTER I.

INTERNAL COMMUNICATION.

Primeval State of Society — Improving the Natural Resources of a Country — Ancient Canals, &c. — Policy of the Romans in establishing Roads — Roman Roads, and system of making them — Turnpike Roads — Introduction of the principle of Railways — "Way Leaves" introduced — Primary Railways — Origin of "Single" and "Double-way" — Wooden Railways — Invention of Cast and Malleable Iron Rails — Cast Iron Edge Rails — Malleable Iron Square Bars — Malleable Iron Edge Rails — Railways, &c. &c.

IN a rude state of society we may infer that man would have little to barter, consequently any other mode of conveyance than that of his own animal power was unregarded; and we have presumptive evidence that improving the natural resources of

every country has been both the cause and effect of civilization: they have, therefore, progressed together.

We may also conjecture, that as civilization exercised its influence on man his wants would increase: and further, that a great part of the product of his industry would be a superfluity, until he exchanged a portion of it for that of his neighbours, or for that of other nations. Hence, at the earliest era, we find man inhabiting the shores of lakes and rivers, where his frail bark afforded him a species of conveyance, of which the Indian canoe and Welch river coracle are admirable specimens. Such would be the progress of society.

"Let us travel over all the countries of the earth," says the Abbé Raynal, "and wherever we find no facility of travelling from a city to a town, or from a village to a hamlet, we may pronounce the people to be barbarians."

It would appear from history that the earliest operations of magnitude for improving the natural communications of a country were hydraulic works for the purposes of agriculture, and which were subsequently found to afford the means of an inland navigation. This appears to have been the case with the Deltas of the Nile, in Egypt; the estuaries of the Po, the Rhine, and the Rhone, on the continent of Europe, and many other places.

What length of time elapsed between making these simple canals for the purpose of irrigation and drainage, and ascertaining that they possessed the means of transporting commodities from one place to an-

other, is uncertain; but we are given to understand by Herodotus, in his book Euterpe, that in the reign of Mœris, or five hundred years before the Trojan war, a rise of eight cubits inundated the Delta, making it *navigable for boats*, except the small artificial eminences whereon the towns stood. The same author says (lib. ii.) that a canal was drawn from the Nile above the city of Bubasto; that it passed around a mountain from west to east, and afterwards turned south to the Red Sea. He attributes its commencement to Necos, the son of Psammaticus, 616 B C.; but gives its completion to Darius Hystaspes, 521 B.C. It was four days' navigation, and four ships could pass abreast.

Strabo agrees with Herodotus, and says it was one hundred cubits in breadth, with depth sufficient to carry large vessels (lib. i. and xvii.) He adds, that it terminated at the Arabic Gulf; and that, in his time, the merchants of Alexandria found an outlet from the Nile, in the Arabic Gulf, to go to India. Omar-ebn-el-Kattab ordered Amrou, who had conquered Egypt, about the year 635, to open the canal from the Nile to Quotzoum, on the Red Sea, to *convey the contributions in corn* into Arabia. Elkmaim informs us that it was shut up again by the Caliph Abugia, or Almanzor, in the year 773.

We are also informed, that in China, about 246 B.C., the Prince Tsin-chi-koang, on account of the wars and works he undertook, and the great consumption of his capital, made his subjects carry, night and day, from place to place, many million

sacks of grain, thus making them beasts of burden. And Han, who began to reign in 202 B.C. caused canals to be made to carry rice and other grain from the provinces to the capital, so that all porterage was abolished; but it was not till 86 B.C. that these great works were completed. And Duhalde tells us that the Great or Imperial Canal in China, from the capital, Pekin, in the north, to the city of Canton, in the southern part of the empire, reckoned a distance of nine hundred and twenty miles, is not continued to Pekin, in order that the porterage *may employ* the great population of that quarter!

In the middle of the fourteenth century we read of some magnificent hydraulic works having been executed in the remote regions of India. In the district called the Punjab artificial canals were constructed about 1351, chiefly by Feroze III., who persevered in making these improvements for thirty-seven years. "The country between Delhi, upon the Jumnah (a branch of the Ganges) and the Punjab on the Indus, being frequently without water, this prince undertook to furnish a supply for the purposes of agriculture and *inland navigation;* he therefore built the city of Hipai Ferozeh, about one hundred miles west of Delhi, and caused two canals to be drawn to it. He had previously made a canal from the Jumnah, near the northern hills, to Sufidoon, a royal hunting place; this canal was full sixty miles in length; it passed by Canawl and Joglickpoor; it was about four yards in breadth; he afterwards extended it to Hipai, his new city, when it

was altogether one hundred and fourteen miles in length. About 1626 Shah Ischan made clear out that part which reaches from the hills to Sufidoon, and made a new canal from thence to Delhi, which is about sixty miles."

The other principal canal was from the river Sutledge to the city of Hipai Ferozeh, thus mentioned in Ferushta, translated by Dowe: — " He (Feroze) drew a canal from the Cagger, passing the walls of Sirsutti, and joined it to the river Kera, upon which he built a city, named after himself, Ferozabad; this city he watered with another canal from the Jumnah; these public works were of prodigious advantage to the adjacent countries, by supplying water for their canals, and a commodious *water-carriage* from place to place." Besides these canals connected with Ferozabad, " there are similar works adjacent to Lahore on the south-east bank of the river Hydroates of Alexander. This noble river has its source in the mountains near Nagerkote; it enters the plains near Shapoor, or Rajapan; and it is from this place the canal of Shah Nehr has been carried a distance of about seventy-three miles, to supply the city of Lahore with water." *

Roman Roads. — In all probability the Romans were the first who introduced any regular roads into Great Britain, as the aborigines, at the time of the invasion by Cæsar, were merely barbarians, living chiefly upon what they procured from the chase. The grasping policy of the Romans, it is apparent,

* "Edinburgh Encyclopædia." Art. Navigation Inland.

was, after the subjugation of the inhabitants, to lay the country open by these roads, to facilitate the transport of troops and supplies, in order to keep them in a state of subjection. "The Roman roads," says Mr. Tredgold, "were made so firm and solid, that they have not entirely yielded to the dilapidations of fifteen centuries. These roads (he states) ran nearly in direct lines; natural obstructions were removed or overcome by the efforts of labour or art, whether they consisted of marshes, lakes, rivers, or mountains. In flat districts the middle part of the road was raised into a terrace. In mountainous districts, the roads were alternately cut through mountains and raised above the valleys, so as to preserve either a level line or an uniform inclination. They founded the roads on piles where the ground was not solid; and raised it by strong side-walls, or by arches and piers, where it was necessary to gain elevation. The paved part of the great military roads was sixteen Roman feet* wide, with two side ways, each eight feet wide, separated from the middle way by two raised paths two feet each."

The following account of the construction of these roads, translated from the French Encyclopædia, article *Chemin,* shows that this enterprising people only wanted a knowledge of STEAM, and its application as a motive power, together with a knowledge of the modern system of manufacturing iron, to have adopted RAILWAYS. "They were commenced everywhere by two furrows, measured by a string, these

* "The English foot is to the Roman foot as 1000 : 967."

parallel lines deciding the width of the road; the intervening space was then excavated, and in this depth the several layers of the road-materials were laid, the first being a cement of chalk and sand an inch thick. On this cement, as a first coat, broad and flat stones, six inches high, were placed one on the other, and connected by a very strong mortar; as a second coat, followed a thickness of eight inches of small round stones, softer than the pebble, intermixed with tiles, slates, and the fragments of buildings, all worked to an adhesive substance; and, as a third coat, a thickness of a foot of cement, made from rich earth mixed with chalk. These interior substances formed a road from three feet to three and a half feet thick, and upon this was placed an entire surface of gravel, bound by a cement with a mixture of chalk. This crust is still to be found perfect in several parts of Europe."*.

With the exception of these Roman roads, and the carriages employed thereon, "the width of the wheel-tracks not being more than three feet,"† (and perhaps even these carriages were exclusively, or mostly, devoted to the purposes of war), it appears that the whole of the internal communication of Great Britain was, for centuries afterwards, effected by the employment of what were termed "pack horses," carrying their loads upon their backs, the roads being similar to sheep-tracks. Even at the present time we find in

* Abstract of the report of Joseph Gibbs, Esq., addressed to the London, York, and Norwich committees of the Great Northern Railway Company, as inserted in the "Railway Magazine" for Oct., 1835.

† Rondelet, as cited in Tredgold, 2nd edit., p. 7.

the mountainous districts of Wales, and in the Highlands of Scotland, that the greater part of their commodities are still thus transferred from one place to another.

Turnpike roads, as a means of conveyance, are sometimes preferable either to railways or canals, on account of the comparative trivial expense incurred in their formation: hence a less quantum of tonnage suffices for the capital invested. It is estimated that there are upwards of twenty thousand miles of turnpike road, and one hundred thousand miles of common hard roads, completed in England.

RAILWAYS. — History informs us that the principle of railways, and the reducing of friction, was understood at a very remote period. At the memorable siege of Constantinople, the genius of Mahomet conceived the bold design of transporting his lighter vessels by land for a considerable distance from the Bosphorus to the higher part of the harbour. "A level way," says Gibbon, "was covered with a broad platform of strong and solid planks; and to render them more slippery and smooth, they were anointed with the fat of sheep and oxen. Four score light galleys and brigantines, of fifty and thirty oars, were disembarked on the Bosphorus shore, arranged successively on rollers, and drawn forwards by the power of men and pulleys."

We shall now literally transcribe the descriptions given by our ancestors of some of the primitive railways, or, as they have been aptly termed, "British roadways," for it cannot but be interesting to know

that these were the original source from whence sprung all those truly magnificent lines of inland transit now being ramified in almost every direction. Although it is extremely difficult to say from whom the idea of the railway emanated, the honour of bringing it to the present comparative state of perfection, may, unquestionably, be ascribed to the British nation.

The precise date when railways were invented, or first introduced into this island, is rather uncertain. It has been very justly remarked that in all probability they would be first introduced where the goods were of a peculiar nature, the quantity considerable, and conveyed to one place only, along roads not of the best description. Or perhaps we may suppose that the laying down timber in the worst parts of the road to support the great weights continually drawn upon it, suggested the idea of laying wooden rails for the whole distance.

It may be conjectured that the first railway in England would be formed in the north, wherever the greatest expense was incurred by leading coals from the pits to the place of shipment, by common carts, or panniers on horseback, their only mode of conveyance until the year 1600. A record, in the books of one of the free companies of Newcastle-upon-Tyne, dated 1602, states, "that from tyme out of mynd yt hath been accustomed that all cole-waynes did usually carry and bring eight baulls of coles to all the staythes upon the ryver of Tyne, but of late several hath brought only, or scarce, seven baulls."

It also appears that "way-leaves" were granted for the transit of coal two and a half centuries prior to the above date, but, of course, it would then be carried upon the backs of animals. "In every period of the history of coal mining in the north these 'way-leaves' have formed an important item of expenditure or covenant. '*Sufficiens chiminum*' occurs in the latter sense in a lease to the Prior of Durham in 1354. *Chiminum* is a term often met with in grants of property to monasteries, and implies a right of road to or through the lands appropriated."*

Gray's *Chorographia*, published at Newcastle in the year 1649, says, "Many thousand people are employed in this trade of coales: many live by working them in the pits: many live by conveying them in waggons and waines to the ryver Tyne." And Master Beaumont, a south country gentleman, "of great ingenuity and rare parts, adventured into our mines with his £30,000, who brought with him many rare engines not known then in those parts, as the art to boore with iron rodds, to try the deepnesse and thicknesse of the coale; rare engines to draw water out of the pits; waggons with one horse to carry down coales from the pits to the staythes, to the ryver." From which it would appear that Mr. B. would probably be the first who introduced wagons, and perhaps "wagon-ways," as they were then termed, into the north.

Lord Keeper Guildford, who was upon the northern circuit in 1676, thus describes the above:—"The

* "Fossil Fuel, the Collieries and Coal Trade," p. 349.

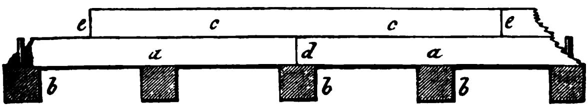
manner of carriage is by laying *rails* of timber from the colliery to the river, exactly straight and parallel; and bulky carts are made, with rollers fitting those rails, whereby the carriage is so easy, that one horse will draw down four or five chaldron of coals, and is an immense benefit to the coal merchants."

The following description of the wooden railways is given in *Jaa's Voyages Metullurgiques*, in 1765: — "When the road has been traced, at six feet in breadth, and where the declivities are fixed, an excavation is made of the breadth of the said road, more or less deep, according as the levelling of the ground requires. There are afterwards arranged, along the whole breadth of this excavation, pieces of oak wood, of the thickness of four, five, six, and even eight inches square: these are placed across, and at the distance of two or three feet from each other; these pieces need only be squared at their extremities; and upon these are fixed other pieces of wood, well squared and sawed, of about six or seven inches breadth by five in depth, with pegs of wood; these pieces are placed on each side of the road, along its whole length; they are commonly placed at four feet distance from each other, which forms the interior breadth of the road."

This kind of road was termed the "single-way," but was very imperfect, and destroyed quantities of timber on account of breakage, after being partly worn by the wheels of the wagons, and the frequent perforations near the ends of the sleepers, in fastening down the rails. This destruction of tim-

ber, it may naturally be supposed, would cause many attempts at amelioration, and, probably, the addition of another rail upon the surface of that one which was fastened to the sleeper, was the next improvement, which was afterwards termed the "double-way."

The subjoined figure represents a side elevation of the *modern wooden double railway.* *a a* are the rails fastened down upon the sleepers *b b b*, similar to those of the single-way, which it also represents; *c c* the upper rails laid upon the other, and firmly secured to them by wooden pins, in the same manner



as the other are fastened to the sleepers. In the single-way the joinings of the rails are necessarily upon a sleeper, as shown at *d;* but in the double-way it is not so, for, being fastened *upon* the under rail, which presents a continuous bearing, they can be secured anywhere along it. *e e* shows the joinings of the upper rail, midway between the cross sleepers, but they may be varied according to the upper lengths of timber. This prevents the under rail from being destroyed by the frequent perforation of the pin holes in receiving the upper or wearing rails, and saves the waste of timber occasioned by the use of the single-way.

The sleepers were generally formed of young saplings, or strong branches of the oak, obtained by thinning the plantations. They were six feet long, containing a sectional area of about thirty inches. At their first introduction the under rail was of oak, and afterwards of fir, mostly in six feet lengths, and about five inches square, reaching across three sleepers, each two feet apart. The upper rail was of the same dimensions, and generally made of beech or plane-tree. The surface of the ground being formed pretty even about two yards in width, for the intended "wagon-way," the sleepers were laid down two feet apart, and the rail *a a* pinned to them. The ashes, or material forming the surface of the ground, was then beat firmly underneath the rails, which were thus strengthened and made more rigid; and the upper rail was secured upon the lower by wooden pins. This method was superior to the "single-way." The double rail, by increasing the height of the surface whereon the carriages travelled, allowed the inside of the road to be ballasted to the top of the under rail, being a depth of about six inches upon the sleepers, which secured them against the feet of the draught horses. These roads continued in use for a considerable period of time, in various parts of the island, but especially amongst the collieries of Durham and Northumberland.

The next improvement in railways, says Mr. Hebert, was the substitution of iron for wood, which alone enabled the horse to take double his previous load. This change was not first introduced at New-

castle, as is generally supposed, but at the iron-works of Colebrook-dale, in Shropshire, about the year 1767. Our authority for this statement, continues Mr. H., is derived from the reports of a committee of the House of Commons, on the subject of roads and carriages. It occurs incidentally in a letter to the committee, from the ingenious Hornblower, the rival and contemporary of the celebrated Watt, who observes — "Railways have been in use in this kingdom time out of mind, and they were usually formed of scantlings of good sound oak, laid on sills or sleepers of the same timber, and pinned together with the same stuff."

But the proprietors of Colebrook-dale Iron Works, a very respectable and opulent company, eventually determined to cover these oak rails with cast iron, *not altogether as a necessary expedient of improvement, but in part as a well-digested measure of economy, in support of their trade.* From some adventitious circumstances (which I need not take time to relate) the price of pigs became very low, and their works being of great extent, in order to keep the furnaces on, they thought it would be the best means of stocking their pigs, to lay them on the wooden railways, as it would help to pay the interest by reducing the repairs of the rails ; and, if iron should take any sudden rise, there was nothing to do but to take them up, and send them away as pigs.

But these scantlings of iron (as I may call them) were not such as are now laid in some places ; they

were about five feet long, four inches broad, and one inch and a quarter thick, with three holes, by which they were fastened to the rails, and very complete it was, both in design and execution " * But, prior to the above date (1767), malleable iron was used in the north. It was fastened upon the timber lines by plate-nails, and was much used where the roads were of great curvature.

EDGE-RAILS.—The precise time, or by whom those rails were first introduced, does not distinctly appear. But in the year 1789 Mr. Jessop formed the public railway at Loughborough, in Leicestershire, with cast iron edge-rails, the upper surface of which was elliptical; the wheels of the carriages being provided with proper flanges to guide them upon the road.

About the year 1805, malleable iron rails were tried at Walbottle Colliery, near Newcastle-upon-Tyne; the rails were square bars, two feet in length, joined together by a half-lap joint, with one pin, one end of the rail projecting beyond the end of the adjoining one, two or three inches. Their use was not at that time extended; their upper surface being too narrow, cut the periphery of the wheels, and they were superseded by cast iron rails of greater breadth.

Previous to the year 1820, malleable iron was only used in bars of from two to three feet in length, either flat or in bars, from one to two inches square. They were productive of much injury to

* "Engineers' and Mechanics' Encyclopædia," art. Railways.

the periphery of the wheels, owing to their narrow surface, and if made of greater breadth, and sufficient strength for the carriages to roll along with safety, their expense became much greater than those of cast iron, which made the latter preferred. To remedy these defects, and reduce the number of joinings, &c., Mr. Birkenshaw, of the Bedlington Iron Works, obtained a patent in October, 1820, for making malleable iron edge rails, in lengths of about eighteen feet each, similar in shape to the cast iron ones then used.

It would appear that the first public railway company was instituted at Loughborough, in the year 1789, for the purpose of making a railway a few miles in length; but the first public railway company that prosecuted their works to any extent, was that enterprising body the Society of Friends, who successfully completed that stupendous undertaking the Stockton and Darlington railway, then unrivalled, and which first stimulated British genius to contemplate the forming such gigantic works as have, since that time, been triumphantly effected, despite of all interested, and for a length of time preponderant, opposition.

CHAPTER II.

GRADIENTS.

Of expressing the Rate of Inclinations — Rules for calculating the several parts of Inclined Planes — Tables of Gradients — Rule for ascertaining the proper Inclination, to equalise the Draught in each direction, for a Descending Trade — Examples showing how to calculate by it — Ratio of Wagons of one-third, fourth, and fifth parts of the weights of the gross downward Load, explanatory of the Equalised Planes.

IT may be necessary to observe, that, when speaking of gradients, they are sometimes expressed as at a rate of one yard perpendicular to so many yards horizontal, or at a rate of one foot perpendicular to so many feet horizontal. Such explanations, however, are superfluous, as it is generally understood when we say 1 in 100, 1 in 200, and so on, that the first number represents the perpendicular height, and the latter the horizontal length in attaining such height, and that both numbers are of the same denomination, as yards, feet, &c., unless expressly stated otherwise.

The following rules will explain the method of calculating inclinations, any part being given to find another.* The numbers in the rules refer to similar numbers in the examples.

* See also the Tables of Planes, pages 25, 26, 27, and 28.

Having the inclination, per foot, of a plane given to find the corresponding inclination per mile, chain, or yard; also to find the ratio of the plane.

Rule 1. — Multiply the inclination per foot by 5280 (the number of feet contained in a mile), and the product will be the inclination per mile.

2. — Inclin. per ft. $\times$ 66 = inclin. per chain.

3. — Inclin. per ft. $\times$ 3 = inclin. per yard.

4. — Divide 12 by the inclination per foot, and the quotient will represent the ratio of the plane. If calculated decimally, annex *as many* cyphers to the 12 for a dividend as there are decimals contained in the divisor.

EXAMPLES.

1. — A plane ascending at the rate of $\frac{1}{16}$th of an inch per foot:
$\frac{1}{16} \times \frac{5280}{1} = \frac{5280}{16} = 330$ inches,
or $27\frac{1}{2}$ feet per mile.
By decimals, $\frac{1}{16}$th of an inches $= \cdot 0625$;
and $\cdot 0625 \times 5280 = 330\cdot$ inches,
or $27 \cdot 5$ feet per mile.

4. — Plane ascending $\frac{3}{16}$ths of an inch per foot: *
$\frac{12}{1} \times \frac{16}{3} = \frac{192}{3} = 64$, ratio of the plane, 1 in 64.
By decimals,
$12 \cdot 0000 \div \cdot 1875 = 64$, ratio of the plane, 1 in 64.

* The above 3-16ths of an inch, and the subsequent divisors, are inverted in order to divide fractionally.

The ascent, per yard, being given to find the same ascent, per mile, per chain, or per foot; also to find the ratio of the plane.

Rule 1.—Ascent per yard $\times$ 1760 = ascent per mile.

2.—Ascent per yard $\times$ 22 = ascent per chain.

3.—Ascent per yard $\div$ 3 = ascent per foot.

4.—Divide 36 (the number of inches contained in a yard) by the ascent per yard, and the quotient will be the ratio of the plane. If calculated decimally, annex cyphers as before.

EXAMPLES.

1.—Plane ascending $\frac{3}{16}$ths of an inch per yard:

$\frac{3}{16} \times \frac{1760}{1} = \frac{5280}{16} = 330$ inches,
or $27\frac{1}{2}$ feet per mile.

By decimals,

$\cdot 1875 \times 1760 = 330$ inches,
or $27 \cdot 5$ feet per mile.

2.—Same plane:
$\frac{3}{16} \times \frac{22}{1} = \frac{66}{16} = 4\frac{1}{8}$ inches per chain.
Decimally, $\cdot 1875 \times 22 = 4 \cdot 125$ inches per chain.

4.—A plane ascending $\frac{3}{16}$ths of an inch per yard:
$\frac{36}{1} \times \frac{16}{3} = \frac{576}{3} = 192$, ratio of the plane, 1 in 192.

By decimals,

$36 \cdot 0000 \div \cdot 1875 = 192$, ratio of the plane, 1 in 192.

The inclination, per chain, being given to find the same inclination per mile, yard, or per foot; also to find the ratio of the plane.

Rule 1. — Inclination per chain $\times$ 80 = inclination per mile.

2. — Inclin. per chain $\div$ 22 = inclin. per yard.

3. — Inclin. per chain $\div$ 66 = inclin. per foot.

4. — Divide 792 (the number of inches contained in a chain) by the inclination per chain, and the quotient will be the ratio of the plane. If calculated by decimals, annex *as many* cyphers to the 792 for a dividend as there are decimals contained in the divisor.

EXAMPLES.

1. — Ascent of plane $4\frac{1}{8}$ inches per chain.

$4\frac{1}{8}$ in. $= \frac{33}{8} \times \frac{80}{1} = \frac{2640}{8} = 330$ inches,
or $27\frac{1}{2}$ feet per mile.

By decimals,

$4{\cdot}125 \times 80 = 330{\cdot}$ inches,
or $27{\cdot}5$ feet per mile.

2. — Inclin. of plane $4\frac{1}{8}$ inches per chain.

$4\frac{1}{8}$ in. $= \frac{33}{8} \times \frac{1}{22} = \frac{33}{176} = \frac{3}{16}$ of an inch per yard.

4. — Ascent of plane $4\frac{1}{8}$ inches per chain $= \frac{33}{8}$,

$\frac{792}{1} \times \frac{8}{33} = \frac{6336}{33} = 192$, ratio of the plane, 1 in 192.

Decimally,

$792{\cdot}000 \div 4{\cdot}125 = 192$, ratio of the plane, 1 in 192.

The inclination, per mile being given to find the the same inclination per chain, yard, or per foot, or to find the ratio of the plane.

Rule 1. — Inclin. per mile÷80=inclin. per chain.

2. — Inclin. per mile÷1760=inclin. per yard.

3. — Inclin. per mile÷5280=inclin. per foot.

4. — Divide 5280 (the number of feet=1 mile) by the inclination per mile. If the latter contain feet and inches, reduce it to inches, and divide 63,360 (the number of inches=1 mile) by the inches in the inclination given, and the quotient, in either case, will represent the ratio of the plane.

EXAMPLES.

1.— Ascent of plane $27\frac{1}{2}$ feet per mile=330 inches.
$\frac{330}{1} \times \frac{1}{80} = \frac{330}{80} = 4\frac{1}{8}$ inches per chain.

Or decimally,

330·÷80=4·125 inches per chain.

2. — Same plane,

330·÷1760=·1875 inches per yard.

4. — Plane ascending 24 feet per mile.
5280÷24=220, ratio of the plane, 1 in 220.

Plane ascending $27\frac{1}{2}$ feet per mile.
63,360÷330=192, ratio of the plane, 1 in 192.

Having the ratio of a plane given to find its inclination per mile, chain, yard, foot, or for any length of it.

Rule 1. — $\frac{\text{5280 feet}}{\text{ratio}}$ = inclin. per mile in feet; or

$\frac{\text{63,360 inches}}{\text{ratio}}$ = inclin. per mile in inches.

2. — $\frac{\text{792 inches}}{\text{ratio}}$ = inclin. per chain in inches.

3. — $\frac{\text{36 inches}}{\text{ratio}}$ = inclin. per yard in inches.

4. — $\frac{\text{12 inches}}{\text{ratio}}$ = inclin. per foot in inches.

5. — $\frac{\text{Length of Plane, in feet}}{\text{ratio}}$ = inclin. of any length of the plane in feet.

EXAMPLES.

1. — Plane ascending at the rate of 1 in 192.

$5280 \div 192 = 27{\cdot}5$ feet per mile;

or $63{,}360 \div 192 = 330$ inches per mile.

2. — Plane ascending at the rate of 1 in 1056,

$\frac{792}{1} \times \frac{1}{1056} = \frac{792}{1056} = \frac{3}{4}$ths of an inch per chain.

3. — Ascent of plane 1 in 192,

$\frac{36}{1} \times \frac{1}{192} = \frac{36}{192} = \frac{3}{16}$ths of an inch per yard.

5. — A plane, 880 yards in length, ascending at the rate of 1 in 192,

880 yards = 2640 feet,

$2640 \div 192 = 13{\cdot}75$ feet = the inclin. of the plane.

MISCELLANEOUS EXAMPLES.

Plane, 2640 yards in length, ascending at the rate of 27 feet 6 inches per mile,

1760 : 2640 : : $27\frac{1}{2}$: $41\frac{1}{4}$ feet=the height of the plane;

or 5280 : 7920 : : 330 : 495 inches=the height of the plane.

Plane, 2640 yards in length, ascends 41 feet 3 inches, what is the inclin. per mile, chain, and per yard?

2640 : 1760 : : $41\frac{1}{4}$: $27\frac{1}{2}$ ft.=the height per mile.

or 7920 : 5280 : : 330 : 495 in.=the height per mile.

2640 : 22 : : 495 : $4\frac{1}{8}$ in.=the height per chn.

2640 : 1 : : 495 : ·1875 in.=the height per yd.

What is the ratio of the above plane, or what length of it=1 yard?

495 : 36 : : 2640 : 192 yards=1 yard, or the ratio of the plane is 1 in 192 yards.

In all such questions as the last, in simple proportion, there will always be three terms, one of which is of the same kind as the answer sought; and the simplest, and surest, way to operate is, to put that term in the third place. It will then readily be seen, whether the answer is required greater or less than that sum, therefore, place the other two terms first and second, according as it is required, less or more; such two terms being always of the same kind, as, inches, feet, &c. In the example

adverted to, the answer was, how many *yards* = 1 yard? The length, 2640 yards, was, therefore, put in the third place. Now, as 2640 yards ascend 495 inches, it was evident that a shorter length would ascend 1 yard. Consequently, the 495 was placed for the first, and the 1 yard (36 inches) for the second term. It is to be observed, that the product of the two means, and that of the two extremes, must always be equal. Thus, in this example, $36 \times 2640 = 95,040$ = the two means; and $495 \times 192 = 95,040$ = the two extremes.

In stating the ratio of each plane, in the last columes of the following tables, the fractional parts have been omitted, and the nearest integral number inserted. And the planes marked with an * in the first table, are the nearest corresponding heights, per mile, to the equal ratios of plane, inserted in the last columns.

Table of Planes,

Showing the rate of Ascent per Mile, and the corresponding Ascent per Chain, per Yard, and also the Ratio.

ASCENT OF PLANE.					ASCENT OF PLANE.				
Per Mile.		Per Ch.	Per Yard	Ratio.	Per Mile.		Per Ch.	Per Yard	Ratio.
Ft.	In.	Inches	Inches.	One in	Ft.	In.	Inches.	Inches.	One in
1	0	·15	·0068	5280	9	4	1·40	·0636	566
1	4	·20	·0091	3960	9	7*	1·44	·0653	550
1	8	·25	·0114	3168	9	8	1·45	·0659	546
2	0	·30	·0136	2640	10	0	1·50	·0682	528
2	4	·35	·0159	2263	10	4	1·55	·0705	511
2	8	·40	·0182	1980	10	7*	1·59	·0722	500
3	0	·45	·0205	1760	10	8	1·60	·0727	495
3	4	·50	·0227	1584	11	0	1·65	·0750	480
3	8	·55	·0250	1440	11	4	1·70	·0773	466
4	0	·60	·0273	1320	11	8	1·75	·0795	453
4	4	·65	·0295	1218	11	9*	1·76	·0801	450
4	8	·70	·0318	1131	12	0	1·80	·0818	440
5	0	·75	·0341	1056	12	4	1·85	·0841	428
5	3*	·79	·0358	1000	12	8	1·90	·0864	417
5	4	·80	·0364	990	13	0	1·95	·0886	406
5	7*	·84	·0381	950	13	2*	1·97	·0898	400
5	8	·85	·0386	932	13	4	2·	·0909	396
5	10*	·87	·0398	900	13	8	2·05	·0932	386
6	0	·90	·0409	880	14	0	2·10	·0955	377
6	3*	·94	·0426	850	14	4	2·15	·0977	368
6	4	·95	·0432	834	14	8	2·20	·1	360
6	7*	·99	·0450	800	15	0	2·25	·1023	352
6	8	1·	·0455	792	15	4	2·30	·1045	344
7	0	1·05	·0477	754	15	8	2·35	·1068	337
7	1*	1·06	·0482	750	16	0	2·40	·1091	330
7	4	1·10	·05	720	16	4	2·45	·1114	323
7	7*	1·14	·0518	700	16	8	2·50	·1136	317
7	8	1·15	·0523	689	17	0	2·55	·1159	311
8	0	1·20	·0545	660	17	4	2·60	·1182	305
8	4	1·25	·0568	634	17	7*	2·64	·1199	300
8	8	1·30	·0591	609	17	8	2·65	·1205	299
8	10*	1·32	·0603	600	18	0	2·70	·1227	293
9	0	1·35	·0614	587	18	4	2·75	·1250	288

ASCENT OF PLANE.					ASCENT OF PLANE.				
Per Mile.		Per Ch.	Per Yard	Ratio.	Per Mile.		Per Ch.	Per Yard	Ratio.
Ft.	In.	Inches.	Inches.	One in	Ft.	In.	Inches.	Inches.	One in
18	8	2·80	·1273	283	45	0	6·75	·3068	117
19	0	2·85	·1295	278	46	8	7·	·3182	113
19	4	2·90	·1318	273	48	4	7·25	·3295	109
19	8	2·95	·1341	268	50	0	7·50	·3409	106
20	0	3·	·1364	264	51	8	7·75	·3523	102
20	4	3·05	·1386	260	52	10*	7·93	·3602	100
20	8	3·10	·1409	255	53	4	8·	·3636	99
21	0	3·15	·1432	251	55	0	8·25	·3750	96
21	4	3·20	·1455	247	56	8	8·5	·3864	93
21	8	3·25	·1477	244	58	4	8·75	·3977	91
22	0	3·30	·15	240	58	8	8·80	·4	90
22	4	3·35	·1523	236	60	0	9·	·4091	88
22	8	3·40	·1545	233	61	8	9·25	·4205	86
23	0	3·45	·1568	230	63	4	9·50	·4318	83
23	4	3·50	·1591	226	65	0	9·75	·4432	81
23	8	3·55	·1614	223	66	8	10·	·4545	79
24	0	3·60	·1636	220	68	4	10·25	·4659	77
24	4	3·65	·1659	217	70	0	10·50	·4773	75
24	8	3·70	·1682	214	71	8	10·75	·4886	74
25	0	3·75	·1705	211	73	4	11·	·5	72
25	4	3·80	·1727	208	75	0	11·25	·5114	70
25	8	3·85	·1750	206	76	8	11·50	·5227	69
26	0	3·90	·1773	203	78	4	11·75	·5341	67
26	4	3·95	·1795	200	80	0	12·	·5455	66
26	8	4·	·1818	198	81	8	12·25	·5568	65
28	4	4·25	·1932	186	83	4	12·50	·5682	63
29	4	4·40	·2	180	85	0	12·75	·5795	62
30	0	4·50	·2045	176	86	8	13·	·5909	61
31	8	4·75	·2159	167	88	0	13·20	·6	60
33	4	5·	·2273	158	88	4	13·25	·6023	60
35	0*	5·25	·2386	150	90	0	13·50	·6136	59
36	8	5·50	·2500	144	91	8	13·75	·6250	58
38	4	5·75	·2614	138	93	4	14·	·6364	57
40	0	6·	·2727	132	95	0	14·25	·6477	56
41	8	6·25	·2841	127	96	8	14·50	·6591	55
43	4	6·50	·2955	122	98	4	14·75	·6705	54
44	0	6·60	·3	120	100	0	15·	·6818	53

Table of Planes,

Showing the Ascent per Yard, and the corresponding Ascent per Chain, per Mile, and also the Ratio.

ASCENT OF PLANE.				
Per Yard.		Per Chain.	Per Mile.	Ratio.
In pts. of an inch.	In decls. of an inch.	Inches.	Feet.	One in
1/64	·0156	·344	2·29	2304
1/48	·0208	·458	3·06	1728
1/32	·0312	·687	4·58	1152
1/24	·0417	·917	6·11	864
1/16	·0625	1·375	9·17	576
1/12	·0833	1·833	12·22	432
1/10	·1	2·2	14·67	360
1/8	·125	2·75	18·33	288
1/6	·1667	3·667	24·44	216
3/16	·1875	4·125	27·50	192
1/5	·2	4·4	29·33	180
1/4	·25	5·5	36·67	144
3/10	·3	6·6	44·	120
5/16	·3125	6·875	45·83	115
1/3	·3333	7·333	48·89	108
3/8	·375	8·25	55·	96
2/5	·4	8·8	58·67	90
5/12	·4167	9·167	61·11	86
7/16	·4375	9·625	64·17	82
1/2	·5	11·	73·33	72
9/16	·5625	12·375	82·5	64
7/12	·5833	12·833	85·56	62
3/5	·6	13·2	88·	60
5/8	·625	13·75	91·67	58
2/3	·6667	14·667	97·78	54
11/16	·6875	15·125	100·83	52

ASCENT OF PLANE.				
Per Yard.		Per Chain.	Per Mile.	Ratio.
In pts. of an inch.	In decls. of an inch.	Inches.	Feet.	One in
$\frac{7}{10}$	·7	15·4	102·67	51
$\frac{3}{4}$	·75	16·5	110·	48
$\frac{4}{5}$	·8	17·6	117·33	45
$\frac{13}{16}$	·8125	17·875	119·17	44
$\frac{5}{6}$	·8333	18·333	122·22	43
$\frac{7}{8}$	·875	19·25	128·33	41
$\frac{9}{10}$	·9	19·8	132·	40
$\frac{11}{12}$	·9167	20·167	134·44	39
$\frac{15}{16}$	·9375	20·625	137·5	38
$\frac{1}{1}$	1·	22·	146·67	36

Descending Planes.—It may be necessary to remark that all lines are considered as descending ones, where there is a constant greater weight drawn in one direction than in the other.

The following rule evinces the method of calculating the proper inclination for gradients of the above description. "To the tonnage in each direction add the weight of the wagons required to carry the greater tonnage, divide the greater sum by the less, and make the quotient, diminished by 1, the numerator, and the same quotient, with 1 added, the denominator of a fraction. Multiply this fraction by the fraction representing the resistance on the level rails, and the result will be the fraction showing the best inclination for the trade."—*Tredgold.*

EXAMPLES.

1. — Suppose that for every 1000 tons of goods conveyed in one direction, there will be only 500 tons drawn in the opposite one; and that the weight of the wagons to carry 1000 tons is 250 tons, ($\frac{1}{5}$ of the gross downward trade)?

First, add to 1000 tons the weight of the wagons, which makes 1250 tons; and to the 500 tons, their weight added will make 750 tons. Divide 1250 by 750; that is $\frac{1250}{750}=1\cdot667$. Then from 1·667 subtract 1 for a numerator, and add 1 for a denominator, and we have $\frac{\cdot667}{2\cdot667}=\frac{1}{4}$. Now if 1 lb. will draw 150 lbs. upon the level railway, then $\frac{1}{4}\times\frac{1}{150}=\frac{1}{600}$, or the plane should descend 1 in 600, to equalise the tractive power thereon.

2. — Again, suppose 1 lb. would draw 240 lbs. upon the level?

then $\frac{1}{4}\times\frac{1}{240}=\frac{1}{960}$, or the plane should descend 1 in 960, to equal the tractive power.

3. — If the empty wagons only were to be returned, and their weight, and the resistance on the level, as in example the first?

then, $\frac{1250}{250}=5$, and $\frac{5-1}{5+1}=\frac{1}{1\cdot5}$;

and $\frac{1}{1\cdot5}\times\frac{1}{150}=\frac{1}{225}$, or a plane descending 1 in 225, would balance the draught.

4. — If the empty wagons only were to be returned, and their weight, as in example the first, the resistance on the level = 240th part as before?

then, $\frac{1}{1 \cdot 5} \times \frac{1}{240} = \frac{1}{360}$, or the plane should descend 1 in 360, to equalise the draught.

5.—Suppose the empty wagons only were to be returned, and their weight was equal to $\frac{1}{4}$th of the gross load, ($\frac{1}{3}$rd of the useful effect), and the resistance on the level equal to the 150th part of that weight?

1000 tons goods + 333, wt. of wgs. = 1333 tons gross. then, $\frac{1333}{333} = 4$, and $\frac{4-1}{4+1} = \frac{1}{1 \cdot 67}$

and $\frac{1}{1 \cdot 67} \times \frac{1}{150} = \frac{1}{250}$, or a plane descending 1 in 250 would obtain the same result, as 1 in 360 does in the last example.

6.—Suppose the empty wagons only were to be returned, and that their weight equalled $\frac{1}{3}$rd of the gross load ($\frac{1}{2}$ the useful effect)?

1000 tons goods + 500, wt. of wgs. = 1500 tons gross. then, $\frac{1500}{500} = 3$, and $\frac{3-1}{3+1} = \frac{1}{2}$ or the descent should be equal to $\frac{1}{2}$ the resistance upon the level.

According to the weights, &c., given in the first example, it appears that the proper inclination should be $\frac{1}{4}$th of the resistance upon the level railway; in the second equal to $\frac{1}{1 \cdot 5}$th, and so on, to equalise the draught in each direction. It will also be observed that the equalised draught alters the proper declivity according to the ratio of weight that the wagons bear to the gross load. The lighter they are, of course the greater acclivity is requisite to balance the preponderating downward trade.

We shall now proceed to show that the preceding inclinations of plane are correctly balanced.

1. — Supposing a power of 100 lbs. be applied upon a railway where the resistance upon the level equals the 150th part of the insistent weight, what weight will it draw down a plane of 1 in 600 ?

$100 \times 150 = 15{,}000$ lbs., drawn on the level ;
then, $15{,}000 \div 150 = 100$ lbs., friction on the level ;
$15{,}000 \div 600 = \underline{\ 25}$, gravity of plane ;
75 lbs., total resistance.

and $\frac{100 \times 15{,}000}{75} = 20{,}000$ lbs. = the weight drawn down the plane.

2. — The resistance upon the level being the same, what weight would the 100 lbs. power draw up the same plane ?

Here, the resistance upon the level must be added to the gravity of the plane. Friction on the level, 100 lbs. + gravity, $25 = 125$ lbs., total resistance. And $125 : 100 :: 15{,}000 : 12{,}000$ lbs. = the weight drawn up the plane. And the 20,000 lbs. drawn down in the last example : this 12,000 lbs. : : 1250 tons : 750 tons, returned in the first example in page 29. Consequently it proves that a plane descending 1 in 600, $(\frac{1}{4} \times \frac{1}{150})$ equalises the draught, where the weights drawn in each direction, and that of the wagons is as there described.

3. — If a power of 100 lbs. were applied on a railway, where the resistance on the level equalled

the 150th part of the insistent weight, what weight would it draw down a plane of 1 in 250?

$100 \times 150 = 15{,}000$ lbs., drawn on the level;

then, $15{,}000 \div 150 = 100$ lbs., friction on the level;

$$\begin{array}{rl} 15{,}000 \div 250 = & \underline{60}, \text{ gravity;} \\ & 40 \text{ lbs., total resistance.} \end{array}$$

and, $\frac{100 \times 15{,}000}{40} = 37{,}500$ lbs. = the weight drawn down the plane.

4.—What weight would the 100 lbs. power draw up the plane of 1 in 250, the resistance on the level being the same as in the last example?

Here, the friction upon the level must be added to the gravity of the plane. Friction on the level, 100 lbs. + gravity, 60 = 160 lbs. total resistance. And, 160 : 100 : : 15,000 : 9375 lbs. = the weight drawn up the plane, and $= \frac{1}{4}$th of the descending load. It consequently follows that a plane descending 1 in 250 $(\frac{1}{1 \cdot 87} \times \frac{1}{150})$ = the tractive power, where the load is only in one direction, and the weight of the wagons $= \frac{1}{4}$th of the gross load. See example fifth in page 30.

CHAPTER III.

EXCAVATING.

Land required for Railways — Methods of Working Slopes — Soiling Slopes - Angle of Slopes — Batter of Slopes explained — Boring -- Side Cutting and Spoil — Systems of Excavating — Blasting Earth — Cubic Yards excavated per Day by each Individual — Expense of excavating per cubic Yard — Barrowing — Regulating Barrow Roads and number of Men requisite to work them — Single and Double Horse Runs — Various modes of Gulleting — Wagon Filling — Plan of Laying Roads and Sidings — Excavating in layers — Descending Cuts — Filling to advantage — Modes of Excavating Rock — Machinery used in Rock Excavations — Patent Safety Fuse — Immense Explosions of Rock on the South Eastern Railway, &c. - American Patent for Boring in Rock — Formation Level — Slips and Drainage of Slopes — Bench Drains — Preserving Slopes — Dwarf Walls, &c. — Timbered Excavations - Excavating Square Shafts -- Size of Shafts and Dimensions of Timber — Method of Timbering - Poling — Suspending Timber Framing in Shafts by Hanging Rods — Trussed Framing — Iron Saddles — Supporting Shaft Timber from Bottom — Packing and Wedging -- Outbursts of Sand and Water — How Managed -- Pressure on Timber — How Supported Hand Poling — Sinking Sumps — Screwing Shields -- Shaft-lengths of Tunnel — How " Widened out " from Square Shafts — Quantity of Timber and Iron nsed in Pits — Engines, &c., &c.

THE quantity of land requisite for forming railways will depend upon various circumstances, such as an undulating surface, depths of cutting, heights of embankments, &c. ; but for a double line about thirty yards may be assumed as a medial breadth, or about eleven acres per mile.

The line having been fenced off, the first operation is to remove the surface soil from the site of the

intended earthworks, depositing the same carefully outside the slopes. This may be effected by ploughing the soil, and removing it by three-wheel carts, wheeling, &c.; or it may be removed by barrow work. Sufficient soil must be provided from the cuttings for soiling their slopes and the upper part of the embankments. Where soil is scarce underneath the latter, it must be provided from the cuttings for soiling the whole slopes: indeed it will often be found preferable to soil the embankments wholly with the soil from the cuttings, as it is removed from thence to the former with less labour than from their base.

Soiling the slopes and sowing with hay-seeds not only improves the appearance of the line, but also forms a good preventive against the destructive influence of the atmosphere. When the grass has once attained a proper sward it acts as a shield, and being nearly impervious to wet, when lying in a sloping direction, prevents the rain from penetrating the slopes and washing the material into the side drainage; indeed, many kinds of slopes are protected when soiled only, as the atmosphere does not act so destructively upon surface soil as upon that obtained at a greater depth. Soiling is also a good method to adopt either with excavations or embankments, when composed of sand or other loose material, in order to form an outer crust to protect the slope against the powerful force of the wind, which frequently indents this kind of work to a considerable extent.

In performing deep excavations the greatest precaution will be necessary to preserve the uniformity of the slopes, and to keep them free from hollows or abrupt places, which not only disfigure, but also tend to cause disruptions in them; besides, when there is a surplus of cutting, every hollow causes the expense of removing an extra quantity of material. Moreover, an expense frequently incurred by re-dressing slopes would also be avoided by taking due precaution to work them properly during the several stages of the work. To accomplish which, we prefer the method of cutting niches down the slopes at intervals, commencing at the surface slope pegs, and finishing them with a proper bevil, agreeing with the angle of the slopes. These serve as proper guides, and if carried down carefully will correspond together when the cuts are finished, and enable the slopes to be dressed off as the upper layers are removed; thus saving a great deal of labour in trimming and casting the material down the slopes.

Attention should also be paid to the angle of the slopes, they being regulated by the nature of the material and the depth of the cutting, for the deeper the cut the flatter ought they to be executed, that is to say, when composed of similar material.

In earthwork, if the slopes are stated to be 1 to 1, 1½ to 1, 2 to 1, &c., it is understood that the latter number represents the perpendicular height, and that both figures are of the same denomination as feet, yards, &c. &c. In rock the same remark will

apply to the slopes or sides of the excavation, namely, ¼ to 1, ½ to 1, and so on.

It is essential to have the earth perforated at various places to the depth of the intended excavations, particularly where they are to be of great depth, in order to ascertain what the strata are composed of. Where cuttings are shallow this is easily effected, but where they are deep recourse must be had to the sinking of shafts, as that method is far preferable to boring only.

The requisite cutting for forming embankments may in general be nearly ascertained, provided the ground be firm, but where the foundation yields by the pressure there are no data upon which to form one. Embankments in ordinary soils may usually be supposed equivalent to cuts of corresponding depth, on account of their slipping and waste before being finally consolidated; in dry material, however, the latter will form a surplus.

When lines have to be expeditiously formed it sometimes happens that part of the excavation has to be run to spoil, and a similar quantity of material procured at some more convenient place to complete the embankment. This of course increases the quantity of excavation, but the required rate of progress probably cannot be attained otherwise.

The chief object to be accomplished when excavating, or what is termed "getting the earth," is to cause its specific gravity to assist in overcoming its tenacity. This is easily obtained by merely undermining it, where there is a good breadth of face;

but where the breadth is limited, we prefer cutting an upright niche, about two feet wide at each end, to the extent of the intended fall. Having the material thus projecting, its gravity greatly assists in detaching it in large masses, many tons each. The labour of cutting those niches is far more than compensated by the trivial dressing requisite before another fall takes place. Working some soils is yet further expedited by placing a block a short distance from the face. The earth in falling acquires such a considerable force that when it comes in collision with the block it becomes comparatively ready for being loaded.

When the earth is hard recourse is often had to blasting it with powder. Iron rods from five to ten feet in length, and about two inches in diameter, are used for making the holes in the ground. The best shape for the head of the rod, we have found to be six inches from the bottom, about half an inch thicker than the rod, and tapered regularly to a point at the bottom. These are known to workmen by the name of "*rose-bud heads*." They make the holes rather larger than the diameter of the rods, which both greatly facilitates their driving and withdrawing.

The quantity of excavation performed in a specified time, by each workman, is very fluctuating, the tenacity of the earth alone frequently making a difference of more than one hundred per cent., exclusive of the difference made by the variations of seasons, which it is well known materially affect the

progress of works of this kind In many soils we have known each man in the cut to excavate and load twelve cubic yards per day; whereas, in others, each man scarcely averaged one-half that quantity, even after the earth had been detached from the face. Yet, upon the average, in ordinary soils, we may fairly assume eight cubic yards of earth to be cut and loaded by each individual employed *in the cut* for his day's work; and, at an average of three shillings per day, the expense of excavating and loading would amount to 4·5 pence per cubic yard. But where works are pushed, especially during unfavourable weather, it considerably enhances the cost of excavating. Indeed in works of this nature there are so many contingencies, that, to estimate the quantity and value, they must be examined by those conversant with such undertakings.

In excavating, where the distance is short, barrowing is preferable to any other means, to the extent that manual power can be appropriated, on account of the simplicity of the machines and the readiness with which stages are erected for their application. Indeed, we may truly say, that the quantity of earth removed in them per diem, by some workmen, is almost incredible.

The usual way to regulate this kind of work is to ascertain how many men will be required to work the road. Thus, some kinds of material will require one man to *get* the earth, three fillers to load and spurn out (that is, to fill the barrow and run it from the face along the branch plank to where it inter-

sects the main road), and one runner to run from the latter place, a distance of twenty yards, and tip the barrow. This is termed a five-man road. If this latter distance were forty yards from the spurn out, two runners would be requisite, and therefore it would become a six-man road, and so on for every additional runner.

Roads are also worked with four fillers, each man getting, filling, and spurning out his barrow, and the runner on the main road running and tipping at a shorter distance, say about sixteen yards; or, if the earth be rather hard, the road will be worked in the same manner, and an additional man will be employed at the face, as getter; but this latter method is not considered a full run, as the earth is not removed the proper distance of twenty yards. Sometimes to expedite a cutting (and where there is sufficient space for the fillers) double the preceding numbers are employed, and two runners on every twenty yards: these are termed double-roads.

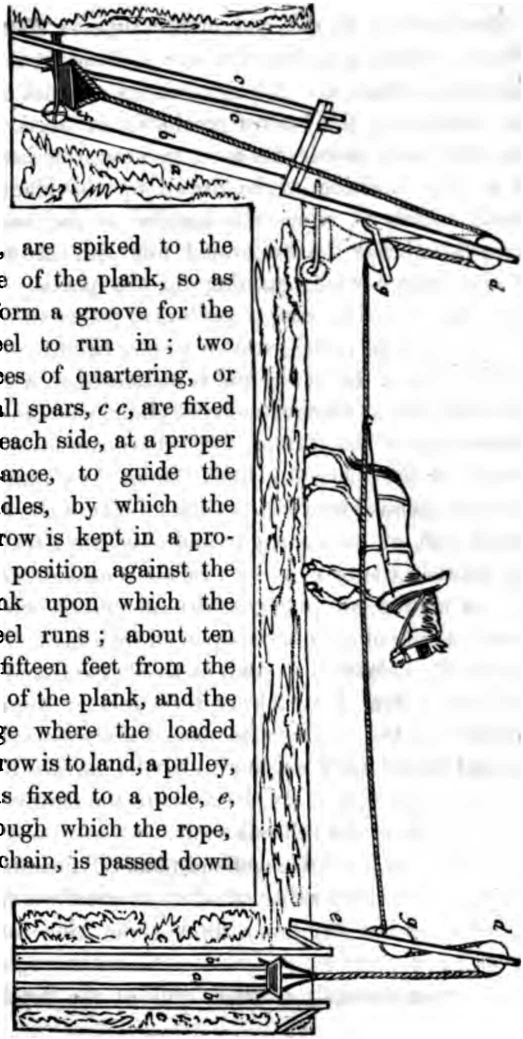
For greater distances, the best mode is to use small wagons, or corves, placed upon trams; in either case running upon tram-ways, impelled by the workmen. Where the nature of the soil is such that it is readily unloaded, these two latter methods are often preferable to the former, even for short lengths, but for the greater facility with which barrows are applied, owing to a single plank in width sufficing for a roadway. Small wagons are also used in some places drawn by horses, having a single road only, without sidings, the empty wagons being

turned aside anywhere to allow the full ones to pass, but of course this method only answers where the quantity is limited.

Three-wheel carts are also very useful on public works for such purposes as removing the upper lifts of a cutting to spoil, completing smaller cuttings, removing soil, &c. Requiring no road to be laid to run upon, they may be used to advantage for any length of time, however short; and, as the distance of removal becomes too great, they are easily transferred from one part of the line to another.

Horse Runs. — In limited situations, where the earth is to be lifted from a lower to a higher level, recourse is often had to what are termed *horse-runs*, that is to say, where the planks forming the roadways are laid almost vertically, one man being drawn up along with a loaded barrow, whilst another man is being lowered down a similar plane with an empty one; or alternately drawn up and lowered down the same plane. The frequency of accidents upon such roads led to the following improvement.

The engraving on the opposite page represents the plan alluded to, invented by Mr. Matthews, and which has been rewarded by the Society of Arts by an honorary gold medal. By its adoption accidents are entirely avoided, as the barrows are alternately drawn up and lowered down without any workman accompanying them. It is thus given in the work referred to, page 15. *a a* is a plank ten or eleven inches wide, laid at a small angle, sufficient to keep the barrow wheel in contact with it, and two strips,



b b, are spiked to the edge of the plank, so as to form a groove for the wheel to run in ; two pieces of quartering, or small spars, *c c*, are fixed on each side, at a proper distance, to guide the handles, by which the barrow is kept in a proper position against the plank upon which the wheel runs ; about ten or fifteen feet from the top of the plank, and the stage where the loaded barrow is to land, a pulley, *d*, is fixed to a pole, *e*, through which the rope, or chain, is passed down

to the barrow; to the end of the rope is fastened a hook, which goes into the eye *f*, fixed upon the point of the barrow. A pair of slings are slid upon the handles of the barrow previously fastened upon the rope at a proper distance, to keep the barrow in a right position to be drawn up the plane, or plank, which is, when the handles of the barrow are a little below the horizontal line with the wheel of the barrow while running up the plank. The rope, after passing over a pulley, *d*, passes through another leading pulley, *g*, at a proper height to suit the draught of the horse, and is connected to a similar apparatus at another inclined plane, situated at a distance from the former, somewhat exceeding the length of the planes on which the barrows run. A horse is attached by a rope to the middle of the horizontal part of the rope, *g g*, and alternately traversing between the two stations, raises a loaded barrow at one station, or plane, whilst an empty one descends at the other, unaccompanied by a man. The pulley, *d*, is elevated so high as to let the rope from the barrow clear the bank, and yet incline so much inward that the barrow clears the bank as it swings in, and lands itself as shown by the dotted lines. The man has only to fix the ropes to the empty barrow, and wheel the full one away.

GULLETING. — An excellent plan of forwarding earthworks is the making of what is usually termed a *gullet*, or the forming a ditch about nine feet in breadth along the excavation. The gullet ought to be cut from one-half to two-thirds of the depth of

each layer, the contents being thrown on the top, and the bottom part afterwards excavated to the full depth, and loaded into the wagons. This admits a train of wagons to pass forward into the interior of an excavation, and is peculiarly well adapted to the upper layers of deep cuttings; where, by making this single road forward, the whole breadth, for any length of the cut, is rendered available; and the earth being loaded into the wagons over their sides, a train of almost any length may be loaded at one time.

Gullets should not be cut to the full depth before commencing to load the earth into the wagons, except for some particular purpose, or where the material is good. Casting out the bottom part is too expensive, moreover the produce has to be refilled. The sides are also more liable to be pressed in, owing to their being a greater weight resting upon them, and by their extra depth. There will generally be sufficient time to excavate the bottom part of a gullet, and load the produce into the wagons most advanced into the interior, without its being cast out and refilled, as the other wagons have to convey the whole depth of the layer, and also the produce of the gullet.

Sometimes it is advisable to work the gullet extra time; and, whilst the cut is in full operation, to work the former in two or three lifts, wheeling the produce into the wagons nearest the face instead of casting it out as above. This answers the purpose providing the gullet makes due progress, keeping

sufficiently in advance to allow the proper number of wagons to be loaded each time. It also considerably assists in tipping many kinds of earth during wet weather.

In sidling ground the low side of the cut gives great facility for progressing with the gullet, the quantity to move being inconsiderable compared with the opposite side; but when the earth lies all on one side, and has to be filled off one road, there is often a delay in replacing the empty wagons. When thus situated, it is advisable to keep the siding as near as possible to the face, to enable the empty wagons to be drawn in immediately the loaded ones run out. Sometimes the siding can be made long enough to extend beyond the place where the earth is loaded; in which case the empty wagons are drawn on this siding to that point, when they are put upon the main road and attached behind to the full wagons. The empty ones are thus drawn opposite the filling, where they are unhooked, the loaded wagons passing forward to the tip. This is an excellent method of operating where it can be accomplished.

When speaking of the advantages of gullets, it is necessary to remark that they are frequently prosecuted to too great an extent, especially in winter, or during a wet season. Being made so much in advance of the finished layer, they are too long exposed, and, by the action of the weather, large quantities of the excavated earth and sides of the gullet are precipitated into the bottom, and only removed at a great expense.

Gulleting is incompatible with smaller cuttings, unless that, by making a road through an intervening space, it enables a cut of greater magnitude to be commenced. It is occasionally resorted to for expediting the work of the former, (although attended with additional expense), for the advantages resulting from the residue, after the gullet is made, will not compensate for its execution. But where cuttings are very shallow, gulleting is generally preferred to enable the material to be loaded as previously described, otherwise the rate of progress would be very trifling indeed.

EXCAVATING IN LAYERS. — Where cuttings are of great magnitude, it is expedient to excavate in layers in order to diminish the danger attending those works as much as possible, and also to facilitate their progress. Each layer ought to proceed with an uniform descent towards the place of delivery, on account of conveying the water from the face, and to assist the draught. By operating in this manner a second layer may be proceeded with so soon as a length of the first is wide enough to admit of it, and the succeeding layers worked similarly, thus having all proceeding at the same time. And should the upper layers be sent to spoil, the work is then almost unlimited.

When excavations are performed to the required depth in two layers, they should progress together, keeping the upper one any convenient distance advanced, and its produce conveyed to the lower by an inclined plane on one of the slopes. This equalises

the work, the higher layer being so much better adapted for excavating on account of its extra breadth.

DESCENDING CUTS.—In making these cuts the water is frequently very troublesome; it is therefore desirable that the greater part should be executed on a level, or with a slight ascent, in order to lessen the inconvenience of quitting the water, and only have it to contend with when engaged in the bottom. If there be a great accumulation of water in the latter, and it be difficult to quit, the most effectual mode is to make an open drain from the lower end of the cutting after the water level line is carried through.

We have occasionally observed cuts slightly descending worked to the specified depth as they proceeded merely by keeping the face, and a short distance from it, a few inches above the proper depth, and bottoming the cut as it advanced, which kept the part in operation free from water.

Another mode of performing a descending cut where part of the produce is required for embanking at each end, is to convey the upper part of the excavation into the ascending embankment, and afterwards bottom it to form the descending one. In fact it is frequently advisable to remove the lower end of these cuts into the adjoining embankment, although perhaps taken in the wrong direction. These methods necessarily increase the average length of conveyance, yet the advantages consequent therefrom will far more than compensate for the additional distance.

On all works due attention must be paid to keep the roads in good repair, to prevent accidents and stoppages occurring; also to have the succeeding parts of the work properly opened out by the time those in hand is completed, and always have other roads ready to fill off by the time the present filling is out of reach. Fillers work to great disadvantage when too far from the wagons, and of course every effort ought to be made not to throw them out of employ.

EXCAVATING ROCK. — In ordinary rock excavations many of the preceding methods may be adopted, but where they are of great magnitude it will generally be advisable to proceed in layers, and to employ as little staging as possible, owing to the destruction made with it whilst blasting. The gullet may either be made along the centre or adjoining one side of the cut. If the latter, it will form one side of the work when completed; and, if possible, it should be at the *dip side*, which greatly facilitates both the winning and removal of the remainder. After sufficient space is obtained in the upper lift for a reasonable distance, the lower end of the road may be turned a little, and then the succeeding gullet in the next layer proceeded with, and so on. If the gullet be made along the centre, another can be made in the succeeding layer as the excavation is removed from the upper one. In either case the work may be prosecuted at whatever rate is deemed necessary, by breaking in additional faces to widen out as the gullet is completed; and the progress of

the latter may be increased by additional faces along it, depositing the contents on the sides thereof.

To expedite the progress of rock excavations of limited breadth, we would suggest that they should be formed in layers of about fifteen feet each, in two depths, which would allow of any space in the upper part being excavated at one time. Each layer might thus be prosecuted at whatever rate was deemed necessary, merely by increasing the number of faces along its upper part, and depositing the contents upon the top of the lower, to be removed as the lower part of the layer advanced. By adopting this plan, or opening out the work as previously described, it allows the excavating to be accelerated without curtailing the space occupied by each workman, and enables the winning of each separate face to be undertaken by a different gang of workmen, which is, in many cases, a great acquisition.

Travelling cranes and other machinery are also very useful upon works of this kind, and tend greatly to forward the progress by removing large masses of stone when detached from the face, instead of drilling and blasting them. Cranes on top moving on a railway are also often of great use in loading wagons underneath, and in hoisting stones to the surface, either to be sent to spoil or used for any other purposes.

A very useful invention for these hazardous works consists in the Patent Safety Fuse, used for safely conveying fire to the charge in blasting rocks. It is made of flax, having in the centre a column of fine

gunpowder; and has superseded the old system of the needle, with all its dangerous appendages.

The following blast of rock took place in Craigleith quarry, near Edinburgh, on the 18th of October, 1834, "At half-past two o'clock, the conductor, inclosed in a block-tin tube, twenty-six feet long, and half an inch diameter, was introduced into the bore. The depth of the bore was sixty feet, and seven and a half inches diameter at top, and six at the bottom, and was charged with five hundred pounds of Sir Henry Bridge's double-strong blasting-powder. At half-past three, the match was lighted, and in three minutes the explosion took place. The report was not so loud as from a small piece of ordnance; but the effect that was produced was highly satisfactory. It is calculated that upwards of twenty thousand tons of solid rock have been displaced by this experiment."*

The above, however, appears trifling when compared to the two immense blasts which took place on the South Eastern Railway. The first was effected at the Round Down Cliff, near Dover, on the 26th January, 1843. The powder was deposited in three charges; three proper chambers having been excavated, seventy feet apart, near the foot of the rock, for receiving the same, which is here about four hundred feet in height above the railway. The two end chambers were about forty-five feet, and that at the centre seventy feet, from the face of the cliff.

* The Edinburgh Observer, as quoted in the Arcana of Science, for 1835.

Into each of the end chambers fifty-five barrels of gunpowder were deposited, and seventy-five barrels for the centre charge, amounting to 18,500 lbs. of powder in the whole! The powder was placed in each chamber in a large deal box, contained in bags of fifty pounds each, having their mouths left open; loose powder being plentifully scattered amongst them. This large quantity of powder was ignited simultaneously in the three charges, by the Galvanic apparatus; it was attended with complete success, about one million tons of rock being removed by the explosion.

The other blast referred to took place near the Round Down, on the first of March, 1843. The object being to remove the upper part of the cliff, to render the railway safer underneath it. Nine chambers were formed, about ninety feet from the top of the cliff, into which 7,000 lbs. of powder were deposited. And, when fired, proved equally successful as the preceding; about 50,000 cubic yards of rock being removed by this second explosion.

In the United States of America, a patent has lately been taken out for forwarding the operation of boring rocks, which is thus described.—"A frame is made, in the centre of which an iron shaft or rod is caused to rise and fall vertically between friction rollers, so placed as to keep it in its position. In the lower end of the shaft a socket is formed, to receive drills of different sizes. Provision is made for placing the machine vertically by sliding pieces upon each of its four legs, which serve to

lengthen them as may be necessary. The apparatus, for working the shaft up and down, is formed as follows:—A circular plate of iron, about a foot in diameter, has a hole in its centre, provided with a socket adapted to the iron rod or shaft, and capable of being secured at any part of it, so that the plate will stand horizontally. At a little distance from the periphery of this plate, an iron spindle crosses the frame; upon this spindle are lifters, which, as it is turned by a crank, come in contact with the lower side of the plate, and raise the shaft; friction-rollers are contained within the lifters, to cause them to slide easily upon the plate, and their action is so managed as to produce a small revolution of the plate, and consequently of the drill, at every lift."*

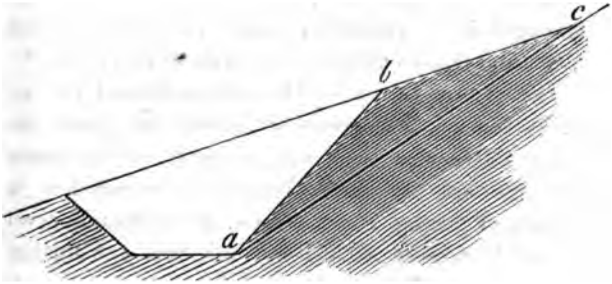
FORMATION-LEVEL.—The bottom should not be perfectly level, but have a few inches fall from the centre of the road, each way, to carry off the water into the side-drainage. When the foundation is tender, or during a wet season, the formation-level should be dressed off and finished from the further end of the work, termed "back-hand work," to prevent the bottom being plunged up by the horses' feet whilst that work is in progress; and the greatest precaution ought to be taken to preserve its uniformity and avoid indentations. The water always accumulates in such places, injures the ballasting, and augments the expense of maintenance.

SLIPS AND DRAINAGE. — In forming many lines

* Journal of the Franklin Institute, as quoted in Hebert's Engineer's Encyclopædia, vol. 2, p. 371.

an enormous expense is incurred by the removal of those huge masses of earth, termed *slips*, which burst from the sides of the excavations. They arise from various causes, but may often be prevented, and often lessened to a great degree. The greatest attention on this point is therefore necessary, as a trifling inadvertency frequently causes serious consequences. It ought always to be borne in mind that it is better to prevent slips than repair them.

Immense slips, however, do occur sometimes, which no precaution could avert. We refer to such



places as backs or faults occurring where the stratification of the earth is nearly horizontal; and of course when a cutting is made is expected still to preserve a state of equilibrium. Or, a cutting made through sidling ground, where the stratification of the earth is much inclined transversely, the whole superincumbent mass above the line of the strata, as shown at *a b c* in the accompanying sketch, is thus left unsupported. If by any means the water should

penetrate — and be powerful enough to disturb or disconnect it — this immense mass may become disunited, and move, in which case the result is incalculable.

Great care must be taken to examine and clear out the surface drains, also to cut off effectually and divert all water communications by land and other drains, likewise all surface feeders, &c.; the object being to render the upper part of the slopes free from surface water, and only have to contend with that found below. If the surface drain be thus required too deep at any place to be left open, it may be cut out and puddled to raise the water course; or passed by a covered drain. The surface must also be very carefully examined for some distance from the edge of the cutting, to ascertain if water enters any where, and if possible prevent, or turn it off; as outbursts in the slopes are frequently caused by the water entering at a considerable distance from the cutting.

Fine regular free-working earth is generally much interspersed with vertical fissures, and the water running down the slopes too readily inserts itself into those places, bursts out lower down the slope, and causes a slip to take place. Should a back or fault be near, and the water enter, the earth becomes disconnected, and a very great slip is the consequence.

Slips are also frequent in irregular ground. They are caused by the water flowing down the slope, entering the tender part and following the vein till it bursts the slope somewhere lower down, often carrying large portions into the side-drainage. If these

outbursts are not immediately attended to, they will make such a breach in the slope that a large slip will, in all probability, speedily follow. Besides, after a slip has been repaired it should frequently be examined, and if a further sinking take place, it must be repaired immediately to prevent the wet entering and causing it to move again.

Wherever water is observed in slopes it is desirable to ascertain the source, and endeavour to turn it off, or partly so; also to drain properly by main drains down the slopes, and branch drains running rather obliquely among them — that is, rising a little from where they intersect the former. Even should the water be less, the slopes ought to be freed from it, and in most cases this will be best accomplished by smaller drains connected with some of the others, or by small upright ones — these being less expensive than the removal of a slip, however trifling it may be.

Rows of hand piling wound with willows, &c., are very useful for keeping the smaller kind of slips in place, after being repaired, until they become properly set, and thus avoid the expense of conveying the earth away. But where much water is found to exist in the slopes, and cannot otherwise be cut off, thoroughly draining them must be considered as the only effectual remedy.

In very deep cuttings the rain should not be allowed to flow down the slopes to the bottom, (as it then becomes very destructive,) but should be collected in an open bench-drain, about midway

down the slope; and either brought down at intervals by proper channels into the side-drainage; or connected at the lower end of the cutting with the surface drains.

Excavations in sidling ground being so subject to be flooded by the water, when escaping from the rising grounds, particular care must be observed to divert it from their high side. Where this is impracticable, the water should be conveyed down the slopes, as in the preceding cases, or across the excavations at the surface, but never allowed to flow down the slopes.

Another protection is to build dwarf-walls at the foot of the slopes, about three feet in height, surmounted with a turf coping to correspond with the slope when soiled, having apertures at suitable distances for the passage of the water from the slope drains. Or, where the bottom of the slopes is soft, to displace part of the earth, and pen it with rubble stone, corresponding with the batter of the slopes.

Timbered Excavations. — The following was a most difficult excavation of this kind, namely, carrying the Bolton and Preston Railway through the Hartwood Green estate, near Chorley, Lancashire, by a tunnel at a depth of eighty feet below the surface

The upper strata were composed of alternate layers of sand, marl, &c. A wet loamy sand followed, which was succeeded by a very quick loamy sand, intermixed with numerous thin seams of clay. The latter was a very treacherous material; so much so, that frequently while it appeared at rest, an

outburst of sand and water, blowing and running furiously, would take place, without the least previous warning. The sand retained the wet so long that its drainage was very questionable; and it was found, when widening the pits for the shaft-lengths of masonry, that it was as quick as ever behind the polings.

In order to avoid the difficulty of taking out shaft-lengths of tunnel from circular pits in the above material, (the ordinary method of tunneling), square or oblong ones were preferred, sufficiently large enough to admit the extreme size of the intended tunnel. Three of these shafts were sunk,* forty-seven feet long by thirty-four feet wide, and supported by balks of timber, termed the main sills, from eighteen to twenty inches square. These were laid horizontally on each side and end of the pits, about three feet six inches apart perpendicularly, but towards the bottom they were laid considerably nearer.

The sills were kept in place and secured by upright props placed between them, and the former stretched with interior timbers, abutting each other horizontally in various directions, and by other timbers strutted and braced in various ways. Behind the sills the pits were close sheeted by a planking three inches in thickness; and when the earth was bad an additional sheeting was resorted to. These immense casings of timber were suspended perpendicularly from the surface of the ground by iron hanging-rods, two inches in diameter, eight being used for each pit.

* Also two circular ones for pumping water.

After the shafts had been sunk to a depth of about fifty feet, the pressure became so enormous and unequal from the shrinking of the earth behind and underneath the timber, especially at the south end of *a* and *d* shafts, that the breakage of these hanging-rods was almost of daily occurrence. To remedy this, a large trussed framing 75 feet in length, and containing 840 cubic feet of timber, was erected across the south end of those pits, extending to a considerable distance at each side upon the solid ground. To these, additional hanging-rods were attached by means of large forged iron saddles, 650 pounds each, which also firmly secured the framing together. The work was now kept nearly stationary for a time, but the material continuing to blow and force itself beneath the lowest sill, as the pits were being sunk deeper, caused such an enormous perpendicular pressure on the timber, and it had such a downward tendency, that it was found impossible to keep the latter in the proper position from the top. The rods were therefore obliged to be abandoned, and the whole timber work supported from the bottom of the pits by being carefully packed solid, and wedged up, underneath the lowest sill. Indeed, the ground was so treacherous, that frequently the outbursts of sand and water would be so sudden that it was with the greatest difficulty those places could be closed again. And it was only by firmly securing — and afterwards tapping regularly — that those places could be recommenced with safety.

In fact, about this depth it was found absolutely

necessary to pack and wedge the spaces between many of the main sills completely solid with timber, where they were every day becoming literally squeezed and riven to pieces. By these means the whole of this immense framing was successfully carried down a distance of twenty feet; that is to say, when the pits were bottomed, the top sills, originally laid rather above the surface of the ground, now rested twenty feet below it; the other timbers, of course, having traversed nearly the same distance. And the earth in this twenty feet had gradually sunk behind the polings, and been drawn to the surface from the bottom, until its sides had run to an angle of rest beyond the back of the shafts, and formed a slope of about 1¼ to 1, commencing a few feet behind the top sills.

It was now found impossible to sink deeper by any of the ordinary methods of hand-poling, therefore inner sills or walings were introduced, and a row of sheet-piling driven by an engine as close as possible in front of the main sills, forming a kind of coffer dam. As the excavation was removed inside those piles, they were secured similarly to the upper timbering; but the pressure behind and underneath was so enormous, that it was found impracticable to proceed with safety lower in each set of piles than within six feet of the bottom.

Having arrived at the bottom, the next operation was sinking the sump to drain each pit. This was a very difficult task. It was performed by having a wooden shield, water-tight at the sides, and suffi-

ciently large to admit the masonry inside. The shield was heavily loaded and screwed down, the inside meantime being excavated. During the progress the bottom heaved much from the pressure, and often had to be abandoned for a length of time until the water eased itself, and thus decreased the pressure.

To complete the excavation was to commence at the top double sill and widen the sides downwards, in order to get the masonry of the shaft-lengths the full size of the pits. The sides being supported by timber and hand poled downwards, as in the upper parts. The total quantity of timber used in the three square pits was 91,346 cubic feet; and of iron thirty-eight tons. Five fixed steam-engines and two portable ones were employed in removing the material and pumping water from the pits on this work, not exceeding three hundred and fifty yards in length.

Although the shafts were all bottomed, and part of the masonry of the shaft-lengths executed, it was deemed advisable to abandon tunnelling, it being evident that process would be very slow and tedious. The line was therefore cut open, and the centre part, for one hundred and twenty-four yards in length, arched and embanked for carrying the Bolton and Preston turnpike road across the same at an elevation of eighty feet above the foundation.

CHAPTER IV.

HAULAGE.

Resistance opposed to the Motion of Carriages upon Permanent Railways — Upon Temporary Railways — Power, Speed, and Distance of a Horse's Day's Work — Distance Travelled, &c. upon Temporary Railways — Cubic Yards of Earth led per Day by each Horse — Weight of Earth-wagons — Weight of Earth per Cubic Yard — Expenses attending Horse Power — Expense of Conveyance per Cubic Yard per Mile — The Tractive Force necessary to Ascend and Descend Planes elucidated — Examples, &c. — Tables exhibiting the Useful Effect per Day of each Horse, in Tons and Cubic Yards of Earth, drawn one Mile; and also the Expense of Haulage per Ton, and per Cubic Yard, upon various Inclinations of Ascending and Descending Planes — Examples showing how the Tables are Calculated — Rules for Calculating the Gross Load, and Useful Effect produced by any Motive Power on a Level, and on Ascending and Descending Planes — Explanatory Examples, &c. — Employing Locomotive and Fixed Machinery for the Removal of Earthworks — Its Advantages and Disadvantages — Elucidation of that Plane upon which the Maximum Effect is produced by Animal Power — Rule for Estimating the Average Lead of Earthwork — Examples, &c. — Tables exhibiting the Resistance opposed to the Motion of Carriages upon various Inclinations of Ascending and Descending Planes — Examples Explanatory of their Use, &c. &c.

Upon permanent lines, the resistance to the motion of carriages is estimated equal to the 240th part of the insistent weight, or 9·33 lbs. per ton; that is to say, if the weight of a wagon and its load amounted to three tons, the traces of a horse drawing it would be stretched with a force equivalent to 28 lbs. An ordinary horse is considered to exert a tractive force of 150 lbs., when travelling at the rate

of two and a half miles an hour; and the duration of his day's work at this speed is estimated at eight hours, equal to twenty miles per day. Whence we have $150 \times 240 \times 20 = 321$ tons, including carriages transported one mile per day by each horse.

But for temporary railways, the friction must be computed at considerably more than the preceding, on account of the subsiding of the road, the quantity of extraneous matter upon the rails, and many other retardations incident to such undertakings; therefore, after making a reasonable allowance for these, and similar imperfections, we may, perhaps, assume the resistence on the level to amount to the 150th part of the weight.

Although twenty miles is usually assigned as the day's work of a horse when loaded, we may calculate a greater distance during the time he is employed in the transmission of earth, as one-half of the space is traversed with the carriages empty. We shall, therefore, in the following calculations estimate it at twenty per cent. more; equal to twelve miles travelling with the load, and twelve in drawing back the empty carriages.

Taking the power of a horse at 150 lbs. we shall then have $150 \times 150 \times 12 = 270{,}000$ lbs. gross removed one mile per day; and deducting one fourth, the weight of the wagons, his performance per day will amount to 90·4 tons of earth transported one mile. A cubic yard of ordinary earth being about 28 cwt. (19·29 cubic feet per ton, or one ton equal to $\frac{5}{7}$ths of a cubic yard,) one horse will convey 64·57

cubic yards of earth one mile each day. Now, suppose we allow for horse-power seven shillings per day, the expense of conveyance per mile will amount to 1·3 pence per cubic yard.

This estimate, and the two haulage tables, page 65, are calculated for a mile length, and are *exclusive* of the expense of drawing the wagons to and fro at the face, and at the tip.* These are very fluctuating charges, regardless of the distance between the face and the latter. It must also be observed, that the cost of conveyance is not exactly proportionate to the distance. Where it is short, the expense per mile will be increased, owing to the loss of time in changing the wagons, and on account of the horses not being fully employed.

With regard to the above price, many works have been executed at that rate, and some even for less, whereas others have cost considerably more. It is a well known fact, that upon these undertakings the prices and quantity of work performed varies very considerably, owing chiefly to their being so many circumstances to contend with over which parties have no control.

It has already been stated that on permanent lines the tractive power necessary to overcome the resistance on the level amounts to the 240th part of the weight moved, or 9·33 lbs. per ton. This resistance is the same whether the road be level or inclined; therefore, in order to draw a weight up any inclina-

* In smaller works the horses employed on the main roads often perform this kind of work, but of course they will then do less per day upon the former.

tion, it is to be overcome in addition to the tendency of the load to fall down the plane — a tendency in the exact proportion of the height of the plane to its length. Thus, a weight of 2240 lbs. when being drawn up an inclined plane of 1 in 240, or 22 feet per mile, has a tendency of the 240th part of that weight, or 9·33 lbs., to fall down the plane. It therefore requires a tractive power twice as great as a level; and for every additional 22 feet per mile that a plane rises, a tractive force of 9·33 lbs. per ton will be necessary for the ascent. It follows that an ascent of 44 feet per mile would require *three* times the force of traction necessary upon a level; 66 feet per mile *four* times that force, and so on. In other words, any given power would only draw one-half the weight up an ascent of 22 feet to the mile, that it would draw along a level; one-third up an ascent of 44 feet, and only one-fourth up an ascent of 66 feet to the mile. But upon temporary lines, where the resistance upon the level amounts to the 150th part of the weight, a plane would be required elevated to 35·2 feet per mile to double the tractive power on a level; 70·4 feet to treble it; and 105·6 feet to cause it to be quadruply increased.

Now, it is *vice versa* when drawing a weight down a plane, by the falling tendency of the load assisting the tractive force in overcoming the resistance, until the declination of the plane causes the gravitating force to be equivalent to the resistance upon the level; when, of course, the weight descends by itself.

Ex. 1. Assuming the friction upon the level to amount to the 240th part of the weight, what power is necessary to draw one ton, (2240 lbs.,) *up* an inclination of 1 in 320?

2240÷240th pt.=9·33 lbs., friction on the level.
2240÷320 =7· gravity of plane.

16·33 lbs.=the power necessary to draw one ton *up* the inclination.

Ex. 2. The friction on the level being equal to the last example, what power would draw one ton *down* the same inclination?

2240÷240th pt.=9·33 lbs., friction on the level.
2240÷320 =7· gravity of plane.

2·33 lbs.=the power necessary to draw one ton *down* the inclination.

The opposite tables exhibit the quantities removed by each horse per day, and also the expense of removal upon various inclinations of ascending and descending planes, agreeably with the foregoing estimation, namely, each horse exerting a tractive force of 150 lbs., and travelling 24 miles per day—twelve miles loaded, and twelve, drawing back the empty wagons.* Horse power and attendance, 7*s*. per day. Weight of wagons, $\frac{1}{4}$th of gross load; earth, 28 cwt. per cubic yard; and resistance on the level $\frac{1}{150}$th part of the weight.

* Except the equalised plane and that of the two following ones in the table of descending planes, where the day's work is estimated at twenty miles.

TABLE OF ASCENDING PLANES.

Ascent of Plane per Chain.	Quantity of Earth drawn 1 Mile per Day.		Expense per Mile in Pence and Decimals.	
Inches.	Tons.	Cub. Yds.	Per Ton.	Pr. cub yd
LEVEL	90·40	64·57	0·929	1·301
0·5	82·58	59·00	1·017	1·424
1·0	76·01	54·29	1·105	1·547
1·5	70·40	50·29	1·193	1·670
2·0	65·56	46·83	1·281	1·794
2·5	61·35	43·82	1·369	1·917
3·0	57·65	41·18	1·457	2·040
3·5	54·37	38·83	1·545	2·163
4·0	51·43	36·74	1·633	2·286
5·0	46·43	33·17	1·809	2·533
6·0	42·32	30·23	1·985	2·779
8·0	35·94	25·67	2·337	3·272

TABLE OF DESCENDING PLANES.

Descent of Plane per Chain.	Quantity of Earth drawn 1 Mile per Day.		Expense per Mile in Pence and Decimals.	
Inches.	Tons.	Cub. Yds.	Per Ton.	Pr. cub yd
LEVEL	90·40	64·57	·929	1·301
0·5	96·40	68·86	·871	1·220
1·0	104·42	74·59	·804	1·126
1·5	115·10	82·21	·730	1·022
2·0	129·54	92·53	·648	·908
2·5	149·62	106·87	·561	·786
3·0	179·28	128·05	·469	·656
3·168	188·33	134·53	·446	·624
3·5	181·22	129·44	·464	·649
4·0	171·45	122·46	·490	·686
5·0	185·73	132·66	·452	·633
6·0	169·27	120·90	·496	·695
8·0	143·77	102·69	·584	·818

It is to be understood that on the ascending planes the earth is conveyed up the inclination, while on the descending planes it is *vice versa*.

On steep ascending planes, such as those in the latter part of the first table, where the gravity of the plane is sufficient to cause the descent of the empty wagons, and convey the horses with them, considerable power may sometimes be gained, but it was considered unnecessary to calculate it for the table. Neither was it deemed requisite to increase the useful effect for the difference between drawing the empty wagons down the planes, or even on planes where they descend by gravity, and that of drawing them along a level. It is sufficient to say that any of the quantities in the first table are equivalent to 90·4 tons of earth drawn one mile per day along a level; the empty wagons returned forming no part of such calculations.*

The day's work for the second table, until the planes exceed 3·168 inches per chain, which equalises the draught, is calculated as explained in the second example (page 69). The descending table shows the maximum effect produced on the equalised plane, descending 3·168 inches per chain (1 in 250), and then a proportionate diminution of effect as the descent of the planes is increased. Of course, a horse can draw a greater weight down the latter planes in the table, than he can draw down the plane of 1 in 250; yet he cannot draw so great a weight up them, as when ascending it; hence the maximum effect produced upon the equalised plane.

* Vide the first example, p. 69.

In consequence of the horse exerting a tractive force of 150 lbs in each direction upon the equalised plane, we have estimated a distance of ten miles in each direction for his day's work when employed upon that gradient.

When the inclination of the descending plane exceeds that whereon the tractive power is equalised, the useful effect is regulated by the weight of the empty wagons drawn up the plane. Our ratio of wagons is computed at the fourth part of the gross load; consequently, the weight of the earth drawn down the plane is equal to three times the weight of the empty wagons drawn up it, per day; which latter weight is assigned in the second table for a horse's day's work.

Upon the plane descending at the rate of 3·5 inches per chain, the horse exerts a tractive force of 150 lbs. in returning the empty carriages, and 91·22 lbs. in drawing them when loaded; and on the following plane he exerts the same power (150 lbs.) when returning them empty, and 62·06 lbs. in drawing them when loaded; while, on the level, he exerts a force of 150 lbs. in one direction, and only 37·5 lbs. in the other; therefore, for the two descending planes, we have only estimated the same length for his day's work as that of the equalised plane.

On the gradient descending at the rate of five inches per chain, a tractive power of only 12·27 lbs. is requisite to draw the loaded wagons; and upon the last two planes in the table, the loaded wagons will descend by gravity, the horses having only to

walk the distance; as on temporary lines it would often be imprudent to cause the animals to be conveyed, lest accidents should befall them. We have made no addition to the useful effect for these three planes, for the difference between the horse exerting a force of 12·27 lbs. on the former — walking one-half of the entire distance, as on the two latter — and that of his exerting a force of 37·5 lbs. when drawing the empty carriages along a level.

It will be perceived that the friction of the empty carriages is estimated at the 150th part of their weight. This, however, is not precisely the case; it being rather more, on account of resistance to motion increasing in rather less ratio than weight.

We shall now proceed to explain the method of estimating the performance of horses, when they are employed upon a level, ascending, and descending planes.

For the level plane,

The power $\times$ resist. on the level $=$ the weight drawn along the level.

For the ascending plane,

$\frac{\text{The pr.} \times \text{wt. drawn upon the level}}{\text{resist. on level} + \text{gravity of plane}} =$ the weight drawn up the plane.

For the descending plane,

$\frac{\text{The pr.} \times \text{weight drawn on the level}}{\text{resist. on level} - \text{gravity of plane}} =$ the weight drawn down the plane.*

* The effect produced upon planes of the above description may be calculated decimally with great facility, as shown in the explanations to the following tables of resistance, in the latter part of the present chapter.

Ex. 1. Suppose a horse be employed on a gradient ascending at the rate of two inches per chain, what will be the result of his day's work. Power, friction, &c. as stated in page 64.

Pr. $150 \times 150 = 22{,}500$ lbs. = the weight drawn upon the level, and two inches per chain = 1 in 396 or $\frac{1}{396}$th part of 22,500 lbs. is to be added for gravity of plane to the friction on the level.

$$22{,}500 \div \overset{\text{th. pt.}}{150} = 150 \text{ lbs., friction on the level,}$$
$$\text{and } 22{,}500 \div 396 = \underline{56{\cdot}82} \text{ gravity of plane;}$$
$$206{\cdot}82 \text{ lbs. total resistance.}$$

then, $\frac{150 \times 22{,}500}{206{\cdot}82} = 16{,}318{\cdot}53$ lbs. = the weight drawn at one time $\times$ 12 miles trav. loaded = 195,822 lbs. gross, — $\frac{1}{4}$th for wagons = 146,866 lbs. = the weight of earth drawn one mile per day.

$146{,}866 \div 2240 = 65{\cdot}56$ tons drawn 1 mile per day.*

$146{,}866 \div 3136 = 46{\cdot}83$ cub. yds. drn. 1 mile per day.

7*s*. $\div 65{\cdot}56 = 1{\cdot}281$ pence per ton per mile.

7*s*. $\div 46{\cdot}83 = 1{\cdot}794$ pence per cub. yd. per mile.

Ex. 2. If a horse be employed upon an inclination, descending at the rate of one and a half inches per chain, or 1 in 528, what will be the result of his day's work. Power, friction, &c. as in the preceding example?

Pr. $150 \times 150 = 22{,}500$ lbs. = the weight drawn upon the level; and for the plane descending 1 in 528,

* 2240 lbs. one ton, and 3136 lbs. equal to 28 cwt., as stated on page 61

$\frac{1}{528}$th part of 22,500 lbs. is to be deducted for gravity of plane, from the friction on the level.

$$\begin{array}{lrl} & 150 & \text{lbs., friction on the level,} \\ \text{and } 22{,}500 \div 528 = & \underline{42{\cdot}61} & \text{gravity of plane.} \\ & 107{\cdot}39 & \text{lbs. total resistance.} \end{array}$$

then, $\frac{150 \times 22{,}500}{107{\cdot}39} = 31{,}427{\cdot}51$ lbs. = the weight drawn down the plane.

On the level plane, the horse returns with empty wagons, amounting to $\frac{1}{4}$th of the gross weight in the loaded direction, or 5625 lbs.; but it would require additional power to draw $\frac{1}{4}$th of the above descending load (31,427·51 lbs.) *up* the plane of 1 in 528. Therefore, we must estimate a number of wagons drawn up this plane equivalent in weight to 5625 lbs. drawn on the level; which, being added to the gross downward load, will be equal to a whole journey to and fro on the level.

Now, a power of 150 lbs. draws 22,500 lbs. upon the level; hence a power of 37·5 lbs. will draw 5625 lbs. upon it.

$$\begin{array}{ll} 5625 \div 150\text{th pt.} = 37{\cdot}5 & \text{lbs. friction on the level,} \\ 5625 \div 528 \quad = \underline{\ 7{\cdot}1} & \text{gravity of plane.} \\ \qquad\qquad\qquad\ \ 44{\cdot}6 & \text{total resistance.} \end{array}$$

then, 44·6 : 37·5 : : 5625 : 4380·84 lbs. = the weight of empty wagons drawn up the plane.

and, 31,427·51 + 4380·84 = 35,808 lbs. × 12 miles = 192 tons = the total weight drawn one mile per day.

The weight of the earth wagons being = to $\frac{1}{4}$th of the gross weight when loaded, $\frac{1}{5}$th of this 192 tons

will be absorbed by returning the empty wagons, and also another $\frac{1}{5}$th by the wagons carrying the downward load, leaving 115 tons, or 82·21 cubic yards of earth, drawn down the plane one mile for the horse's day's work.

The weight of empty wagons drawn up the plane equivalent to 5625 lbs. drawn along the level may likewise be found in the following manner:—

150 lbs., friction on the level,
and 42·61 gravity, as before.

192·61 lbs., total resistance.

and, 192·61 : 150 lbs. power : : 5625 : 4380 lbs.= the weight of the empty wagons drawn up the plane of 1 in 528, as on the opposite page.

The preceding calculations relate to horse power, which is chiefly used in constructing railways; but where extensive works have to be executed in limited situations, such as the middle length of a deep cutting being sent to spoil, or where access cannot be had to commence the ends of it, fixed machinery is indispensable, and tends greatly to facilitate the rate of progress, especially where the gradients to remove the same are necessarily steep.

In practice we have experienced great assistance by working with a double road, namely, where the engine, in drawing up the loaded wagons, was assisted by the gravity of the empty ones descending.

When the distance between the face of a cutting and the tip becomes too great for horse work, it is advisable to get the permanent road completed as

soon as possible. If this desirable object cannot be obtained the temporary road ought to be made firm and solid. Locomotive power may then be introduced with success. It is decidedly preferable to fixed machinery for these purposes, on account of the greater facility with which it can be applied as the length of cutting and embankment becomes increased. It also tends materially to consolidate the road before being open to the public.

It has been previously stated in page 66 that the maximum effect of animal power is obtained on inclined planes, where the tractive force is equalised: there is however an exception, which we now proceed to illustrate.

On permanent lines, or where the road is firm, safe, and kept in good order, the maximum effect will be produced on planes where the loaded wagons have just the requisite gravity to cause their descent at a moderate uniform velocity, and *convey* the horses with them. This, of course, renders a greater tractive force necessary to return the empty wagons; but, at the same time, it must be borne in mind that on such planes animal labour is spared one-half the distance traversed; an advantage which far more than counterbalances the extra exertion whilst returning.

The loaded coal-wagons, which are considered equivalent to 240 times the weight of the moving power, descend planes of 3·5 inches per chain rather too freely, or with an accelerated velocity. Hence it appears that an additional elevation of plane, equal

to 0·2 inches per chain, added to the plane where the gravity equals the resistance on the level, is more than sufficient to gravitate them, at a moderate uniform speed.

But suppose we allow the additional sine of inclination of 0·2 inches per chain, equal to 1 in 3960, to cause the descent of the loaded wagons, and applying the formula to temporary lines, where the friction on the level$=\frac{1}{150}$th part of the weight, we then have $\frac{1}{3960}+\frac{1}{150}=\frac{1}{144\cdot5}$, or a plane descending 1 in 144½.

Now, the horse, by exerting a tractive force of 150 lbs., draws a weight of 6·28 tons of earth-wagons up the equalised plane, ten miles per day; he also exerts the same force in drawing a gross load of four times that weight for ten miles down it =188·33 tons of earth drawn down one mile per day, by a tractive force of 150 lbs., exerted for the length of twenty miles.

On the plane of 1 in 144·5, when exerting the above force, the horse will only draw up 4·93 tons of earth-wagons, yet he will travel twice that distance, or twenty miles up the plane with them per day, on account of his being *conveyed* down it by gravity, and only exerting his power of 150 lbs. in one direction. This makes the distance walked, and his tractive power exerted for a day's work on such plane, equivalent in length and draught to the equalised one. Assuming the weight of the carriage for conveying the horse to be 6·67 cwt., we will then have 4·6 tons of earth-wagons drawn up the plane

each time=338·4 tons of earth drawn down it one mile per day, amounting to 79·68 per cent. more than on gradients where the draught is equalised. And supposing one-tenth of the 338·4 tons to be absorbed by the additional *time* the horse is employed, and for extra allowance to the attendant, we still have 304·56 tons of earth conveyed one mile per day, by each horse, on inclinations of this description, being 61·72 per cent. more than upon equalised ones

Average Lead. — Having ascertained the inclination of the road, in order to know what weight of earth can be drawn at one time, the next question arising is the average distance of leading the whole. The common practice of adding one-half the length of the cut to one-half the length of the embankment answers the purpose where the depth and height are somewhat regular; but should they, or either of them, vary in depth or height as shown in the following section, this method is then incorrect. Thus one-half the length of the cut, in page 76, is seventeen chains, and one-half the length of the embankment fourteen, making thirty-one chains for the average lead; whereas it is shown in the same page that it should be forty-three chains. Were the cut deepest at *a*, and the extra quantity of *a* deposited in *F*, the error would be yet greater, as the average distance would not be increased by such calculation. Now the quantity being increased at *a*, and deposited in *F*, must necessarily lengthen the average lead of the whole. And supposing the cut deepest at *b* instead

of at *a*, the lead would be shortened, and more so were the embankment highest at *c* instead of at *F*; but by the former method of calculating the average distance is in all cases the same; it is therefore clearly erroneous.

When the quantity of earth is considerable, or a great distance to be removed, the average lead becomes important, and therefore should be calculated with accuracy. Those conversant with the subject easily determine a length sufficiently near for practice; but cases frequently occur when the precise length is required, or at least a close approximation. For this purpose we suggest the following rule.

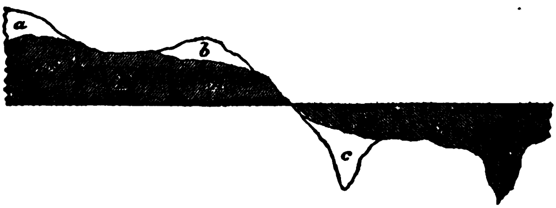
Divide the length of the embankment into separate portions, according to the irregularity of its height, as shown at *D*, *E*, and *F*, and ascertain (from the Earthwork Tables in the latter part of this work) their respective cubic contents. Next measure the depth of the cutting at *A*, and in the same table it will readily be seen what length of *A* is requisite to complete *D*. Or, if the cut be very irregular in depth, it may be taken in different lengths until they will produce a sufficiency for *D*. The parts *B* and *C* are similarly calculated. Multiply the cubic content of each piece of cut, by the sum of one-half its length, one-half the length of each corresponding piece of embankment, and the whole length of each intervening portion of cut and embankment. Add their products together. Divide the aggregate by the total number of cubic yards of cutting, and the

quotient will be the average distance that the whole will have to be conveyed.

Ex. In the following section the contents of the embankment are as follows:—*D*, 7000; *E*, 17,800; and *F*, 25,600 cubic yards; their lengths are 12, 10, and 6 chains respectively, and the several portions of cutting to form the same are

	Cubic yds.		Chains.
A	7,000	and its length	15
B	17,800	. .	11
C	25,600	. .	8

required the average distance that the whole will have to be conveyed?



A 15+D 12=27÷½= . . . 13½ chains.

B 11+E 10=21÷½=10½ chains, and will have to be conveyed through A and D; therefore 10½+A 15 +D 12= . . . . . 37½ chains.

C 8+F 6=14÷½=7 chains, and will have to be conveyed through B, A, D, and E; therefore 7+B 11+A 15+D 12+E 10= . . . 55 chains.

then $7{,}000 \times A\,13\frac{1}{2} = 94500$
$17{,}800 \times B\,37\frac{1}{2} = 667500$
$25{,}600 \times C\,55^{*} = 1408000$

$2{,}170{,}000 \div 50{,}400 = 43$ chains $=$ the average distance that the whole will have to be led.

In the opposite section *C* does not appear so much larger than *A*, as it is in reality, on account of the cubic contents advancing in so much greater ratio than the depth, which may be illustrated by the annexed example. Moreover, the disparity between the cubic contents and the depths would be considerably greater were the latter depth of cutting executed to a flatter slope.

Ex. In the 27 feet column of the first Earthwork Table, slopes 1 to 1, one chain in length

Feet.		Cubic yds.
5	in depth contains	391
10	. . . .	904
20	. . . .	2298
and 40	. . . .	6551

* The three multipliers 13½, 37½, and 55 chains, is the average distance that A, B, and C, have to be led respectively.

Table showing the Resistance opposed to the Motion of a Carriage on different Inclinations of Ascending Planes,

The Friction on the Level being estimated at the 240th part of the Weight.

	Inclination of the Plane equal to 1, in									
	0	100	200	300	400	500	600	700	800	900
0	·00417	·01417	·00917	·0075	·00667	·00617	·00583	·00559	·00542	·00528
10	·10417	·01326	·00893	·00739	·0066	·00613	·0058	·00557	·0054	·00526
20	·05417	·0125	·00871	·00729	·00655	·00609	·00578	·00555	·00538	·00525
30	·0375	·01186	·00851	·0072	·00649	·00605	·00575	·00553	·00537	·00524
40	·02917	·01131	·00833	·00711	·00644	·00602	·00573	·00552	·00536	·00523
50	·02417	·01083	·00817	·00702	·00639	·00598	·0057	·0055	·00534	·00522
60	·02083	·01042	·00801	·00694	·00634	·00595	·00568	·00548	·00533	·00521
70	·01845	·01005	·00787	·00687	·00629	·00592	·00566	·00546	·00531	·0052
80	·01667	·00972	·00774	·0068	·00625	·00589	·00564	·00545	·0053	·00519
90	·01528	·00943	·00761	·00673	·00621	·00586	·00561	·00543	·00529	·00518

TABLE SHOWING THE RESISTANCE OPPOSED TO THE MOTION OF A CARRIAGE ON DIFFERENT INCLINATIONS OF ASCENDING PLANES,

The Friction on the Level being estimated at the 200th part of the Weight.

	Inclination of the Plane equal to 1, in									
	0	100	200	300	400	500	600	700	800	900
0	·005	·015	·01	·00833	·0075	·007	·00667	·00643	·00625	·00611
10	·105	·01409	·00976	·00823	·00744	·00696	·00664	·00641	·00623	·0061
20	·055	·01333	·00955	·00812	·00738	·00692	·00661	·00639	·00622	·00609
30	·03833	·01269	·00935	·00803	·00733	·00689	·00659	·00637	·0062	·00608
40	·03	·01214	·00917	·00794	·00727	·00685	·00656	·00635	·00619	·00606
50	·025	·01167	·009	·00786	·00722	·00682	·00654	·00633	·00618	·00605
60	·02167	·01125	·00885	·00778	·00717	·00679	·00652	·00632	·00616	·00604
70	·01929	·01088	·0087	·0077	·00713	·00675	·00649	·0063	·00615	·00603
80	·0175	·01056	·00857	·00763	·00708	·00672	·00647	·00628	·00614	·00602
90	·01611	·01026	·00845	·00756	·00704	·00669	·00645	·00627	·00612	·00601

TABLE SHOWING THE RESISTANCE OPPOSED TO THE MOTION OF A CARRIAGE ON DIFFERENT INCLINATIONS OF ASCENDING PLANES,

The Friction on the Level being estimated at the 150th part of the Weight.

	Inclination of the Plane equal to 1, in									
	0	100	200	300	400	500	600	700	800	900
0	·00667	·01667	·01167	·01	·00917	·00867	·00833	·00809	·00792	·00778
10	·10667	·01576	·01143	·00989	·00911	·00863	·00831	·00807	·0079	·00776
20	·05667	·015	·01121	·00979	·00905	·00859	·00828	·00805	·00789	·00775
30	·04	·01436	·01101	·0097	·00899	·00855	·00825	·00804	·00787	·00774
40	·03167	·01381	·01083	·00961	·00894	·00852	·00823	·00802	·00786	·00773
50	·02667	·01333	·01067	·00952	·00889	·00848	·0082	·008	·00784	·00772
60	·02333	·01292	·01051	·00944	·00884	·00845	·00818	·00798	·00783	·00771
70	·02095	·01255	·01037	·00937	·00879	·00842	·00816	·00796	·00782	·0077
80	·01917	·01222	·01024	·0093	·00875	·00839	·00814	·00795	·0078	·00769
90	·01778	·01193	·01011	·00923	·00871	·00836	·00812	·00793	·00779	·00768

TABLE SHOWING THE RESISTANCE OPPOSED TO THE MOTION OF A CARRIAGE ON DIFFERENT INCLINATIONS OF ASCENDING PLANES,

The Friction on the Level being estimated at the 100th part of the Weight.

	Inclination of the Plane equal to 1, in									
	0	100	200	300	400	500	600	700	800	900
0	·01	·02	·015	·01333	·0125	·012	·01167	·01143	·01125	·01111
10	·11	·01909	·01476	·01323	·01244	·01196	·01164	·01141	·01123	·0111
20	·06	·01833	·01455	·01313	·01238	·01192	·01161	·01139	·01122	·01109
30	·04333	·01769	·01435	·01303	·01233	·01189	·01159	·01137	·0112	·01108
40	·035	·01714	·01417	·01294	·01227	·01185	·01156	·01135	·01119	·01106
50	·03	·01667	·014	·01286	·01222	·01182	·01154	·01133	·01118	·01105
60	·02667	·01625	·01385	·01278	·01217	·01179	·01152	·01132	·01116	·01104
70	·02429	·01588	·0137	·0127	·01213	·01175	·01149	·0113	·01115	·01103
80	·0225	·01556	·01357	·01263	·01208	·01172	·01147	·01128	·01114	·01102
90	·02111	·01526	·01345	·01256	·01204	·01169	·01145	·01127	·01112	·01101

DESCENDING PLANES.

TABLE SHOWING THE RESISTANCE OPPOSED TO THE MOTION OF A CARRIAGE ON DIFFERENT INCLINATIONS OF DESCENDING PLANES,

The Friction on the Level being estimated at the 150th part of the Weight.

	Inclination of the Plane equal to 1, in								
	100	200	300	400	500	600	700	8 00	900
0	……	·00167	·00333	·00417	·00467	·005	·00524	·00542	·00556
10	……	·00191	·00344	·00423	·00471	·00503	·00526	·00543	·00557
20	……	·00212	·00354	·00429	·00474	·00505	·00528	·00545	·00558
30	……	·00232	·00364	·00434	·00478	·00508	·0053	·00546	·00559
40	……	·0025	·00373	·00439	·00482	·0051	·00532	·00548	·0056
50	0	·00267	·00381	·00444	·00485	·00513	·00533	·00549	·00561
60	·00042	·00282	·00389	·00449	·00488	·00515	·00535	·0055	·00563
70	·00078	·00296	·00396	·00454	·00491	·00517	·00537	·00552	·00564
80	·00111	·0031	·00404	·00458	·00494	·0052	·00538	·00553	·00565
90	·0014	·00322	·0041	·00463	·00497	·00522	·0054	·00554	·00566

The preceding tables exhibit the resistance opposed to the motion of a carriage on various inclinations of ascending and descending planes, from 1 in 10, to 1 in 990. They will be found very useful in abridging calculations either for horse power, or where the motive power is mechanical.

To ascertain the weight any given power would draw up, or down a plane: — Divide the power by the friction given in the ascending or descending tables, adding *as many* cyphers to the power for a dividend as there are decimals contained in the divisor, and the quotient will be the weight drawn up, or down the plane.

Ex. 1. What weight will a tractive power of 150 lbs. draw up a plane of 1 in 340, the resistance being estimated=240th part of the insistent weight?

Look in the left side column of the first table for 40, and for 300 at the top, and where these columns meet will be found the resistance ·00,711.

then, 150·00,000÷·00,711=21,097 lbs.=the weight drawn up the plane.

Ex. 2. Suppose a horse to be employed on a gradient descending 1 in 250; that he exerts a tractive force of 150 lbs., and travels 20 miles per day (ten miles loaded and ten when empty). Weight of wagons $\frac{1}{4}$th of the gross load, and of earth 28 cwt. per cubic yard. Friction on the level $\frac{1}{150}$th part of the gross load. What will be the result of his day's work?

Look in the left side column of the table in page 82 for 50, and for 200 at the top, and where these columns meet will be found the resistance ·00,267.

then 150·00,000 ÷ 00,267 = 56,180 lbs. = the weight drawn down the plane at one time.

and 56,180 × 10 miles loaded = 561,800 lbs., — ¼th for wagons = 421,350 lbs. drawn one mile per day.

and 421,350 ÷ 2240* = 188·10 tons drawn one mile per day,

or 421,350 ÷ 3136 = 134·36 cubic yards drawn one mile per day.†

When the weight which a tractive power will draw along a level is given to find the weight which it will draw up, or down any plane.

$\frac{\text{Resist. on the level} \times \text{given wt.}}{\text{resist. of plane.}}$ = weight which the tractive power will draw up, or down the plane.

Ex. If a horse draw 36,000 lbs. on a level, the friction being estimated at the 240th part of the

* 2240 lbs. one ton, and 3136 lbs. equal to 28 cwt., as stated on the 61st page.

† The actual quantity of earth drawn one mile per day by the above horse would be 188·33 tons, or 134·53 cubic yards, as stated in the descending table (p. 65). The results here being a trifle less, are caused by the recurring decimal ·002,666, which is inserted in the table ·00,267. The last recurring decimal is invariably entered one more when it exceeds 5, which answers best for all practical purposes. In some cases it makes the quantity rather more, in some rather less, as in this instance.

weight upon it, what weight will he draw up a plane of 1 in 240?

In the second column of the first table, opposite 0, will be found the resistance on the level ·00,417. Then look in the first column for 40, and for 200 at the top, and where these columns meet will be found the resistance of the plane ·00,833.

then ·00,833 : ·00,417 : : 36,000 : 18,021 lbs.=the weight which can be drawn up the plane.*

* 18,000 lbs. is the exact weight which he can draw up the plane; the trifling discrepancy occurs from the cause before referred to.

Table showing the Resistance opposed to the Motion of Carriages on different Inclinations of Ascending or Descending Planes,

From 1 in 10 to 1 in 990, by whatever part of the insistent weight they are drawn.

		100	200	300	400	500	600	700	800	900
		·01	·005	·00333	·0025	·002	·00167	·00143	·00125	·00111
10	·1	·00909	·00476	·00322	·00244	·00196	·00164	·00141	·00123	·0011
20	·05	·00833	·00454	·00312	·00238	·00192	·00161	·00139	·00122	·00109
30	·03333	·00769	·00435	·00303	·00232	·00189	·00159	·00137	·0012	·00107
40	·025	·00714	·00417	·00294	·00227	·00185	·00156	·00135	·00119	·00106
50	·02	·00667	·004	·00286	·00222	·00182	·00154	·00133	·00118	·00105
60	·01667	·00625	·00385	·00278	·00217	·00178	·00151	·00131	·00116	·00104
70	·01429	·00588	·0037	·0027	·00213	·00175	·00149	·0013	·00115	·00103
80	·0125	·00555	·00357	·00263	·00208	·00172	·00147	·00128	·00114	·00102
90	·01111	·00526	·00345	·00256	·00204	·00169	·00145	·00126	·00112	·00101

The opposite table shows the resistance opposed to the motion of carriages on different inclinations of ascending or descending planes, from 1 in 10 to 1 in 990, by whatever part of the insistent weight they are drawn.

Ex. 1. To ascertain what weight a tractive power of 150 lbs. would draw up a plane of 1 in 340, the resistance on the level being estimated=240th part of the weight?

Look in the left side column for 40, and for 200 at the top, and where these columns meet will be found the friction on the level, ·00,417 (=240th part of the weight). Opposite, in the adjoining column (300) will be found the gravity of the plane ·00,294; add these two sums together for the total resistance, which will amount to ·00,711. Divide the given power by it, adding *as many* cyphers to the given power for a dividend as there are decimals contained in the divisor, and the quotient will represent the weight drawn up the the plane, thus

Friction on the level, ·00,417
Gravity of the plane, ·00,294

·00,711 lbs.=total resistance.

and 150·00,000÷·00,711=21,097 lbs.=the weight drawn up the plane.

Ex. 2. What weight would the tractive force of 150 lbs. draw down the same plane, the friction on the level being equal to the above plane?

Proceed as in the last example, except that the total resistance is found by deducting the gravity of the plane from the friction upon the level.

Friction on the level, ·00,417
Gravity of the plane, ·00,294
·00,123 lbs.=total resistance.

and 150·00,000÷·00,123=121,951 lbs.=the weight drawn down the plane.

Ex. 3. If a horse draw 36,000 lbs. upon the level, estimating the friction at the 240th part of the weight upon it, what weight will he draw up a plane ascending at the rate of 1 in 240 ?

$\frac{\text{Resist. on level} \times \text{given wt.}}{\text{Total resistance.}}$=weight which he will draw up the plane.

Friction on the level, $\frac{1}{240}$th part=·00,417
Gravity of the plane, $\frac{1}{240}$th part=·00,417
·00,834 lbs.=total resistance.

and ·00,834 : ·00,417 : : 36,000 : 18,000 lbs.=the weight which he can draw up the plane.

Ex. 4. Suppose a horse draws 36,000 lbs. upon a level, estimating the friction as on the preceding planes (240th), what weight will he draw down a descent of 1 in 340 ?

Find the total resistance as in *Ex.* 2.

then, ·00,123 : ·00,417 : : 36,000 : 122,048 lbs.= the weight drawn down the plane.*

Ex. 5. If a horse draws 122,048 lbs. down a descent of 1 in 340, how many pounds will he draw along a level. Friction as before (240th) ?

$\frac{\text{Total resist.} \times \text{given wt.}}{\text{Resist. on level.}}$ = the wt. drawn along the level.

Find the total resistance as in *Ex.* 2.

then, $\frac{\cdot 00,123 \times 122,048}{\cdot 00,417}$ = 36,000 lbs.=the weight drawn along the level.

Ex. 6. Supposing the friction on the level to amount to the 240th part of the weight, and a horse to draw 18,000 lbs. up a plane of 1 in 240, how many pounds will he draw upon the level ?

Find the total resistance as in *Ex.* 3.

then, ·00,417 : ·00,834 : : 18,000 : 36,000 lbs.= the weight drawn upon the level.

* This result and that of example the second would have been alike but for the reason stated in page 84.

CHAPTER V.

EMBANKING.

Of attaining Elevations by Embankments and Viaducts — Constructing Embankments – Angle of Repose of Embankments, &c. — Foundations — System of forming Embankments upon Inferior Foundations — Draining foundations of Embankments — Embanking on sidling ground – Benching foundations of Embankments — Imperfect mode of Embanking — Embanking in Layers – Expediting Tipping — Embanking upon and adjoining Masonry — Counteracting the Pressure of Embankments whilst passing over Culverts or other Masonry – Obstructions in Crossing Valleys – Self-acting Inclined Planes, &c., used when Embanking — Form of Embankments — Benching slopes of Embankments — Tipping Earth — Expense of Tipping — Side-cutting for Embankments — Barrowing — Expansion and Contraction of Earthworks — Soiling and Sowing Slopes — Slips — Draining Slopes of Embankments — Planting Slopes – Preserving Slopes, &c.—Earth-wagons — Improved Earth-wagons – Size, dimensions, particulars, &c., of Improved Earth-wagons – Plan of Improved Wagons, &c. &c.

In forming railways there are often very formidable summits to be attained, either by embanking or adopting the viaductal form. It is almost superfluous to say that the former is preferable when a deposit is wanted for the produce of cuttings. Indeed this is the case at all times where the altitude is not great, even though there be a deficiency of earth, and it has to be procured exclusively from side-cutting; provided the base is not required for some useful purpose.

But, as elevations are increased, embankments

lose their superiority over, and are soon superseded by, viaducts. This is chiefly owing to the rapidity with which their sectional area is increased as they become elevated, and the consequent large quantity of land they require. These increasing effects are not experienced in a viaduct. Arches, spandrels, and every part above the springing, being the same, regardless of altitude. Of course, piers and abutments below the springing will increase, even in greater ratio than height (increased base being requisite for increased height), yet the additional quantity appears trifling contrasted with the former.

The construction of embankments, as well as their requisite quantity, will depend on various circumstances, such as the nature of the earth and the foundation upon which it rests. The height is also of importance, for the angle of rest sufficient for an embankment of fifteen or twenty feet will be inadequate for one (even composed of the same kind of material) of fifty feet. This is especially to be observed whilst forming the lower part of clay embankments.

Embankments formed of small coals, ashes, stone, and sand, &c., are firmest upon the least base, particularly the first, which is much used in the mining districts, being frequently formed of a slope of 1 to 1. But for embankments composed of ordinary earth, of about twenty feet in height, a slope of $1\frac{1}{2}$ to 1 is requisite. Where they are fifty feet or upwards it is advisable to form them about 2 to 1, and in some cases even flatter.

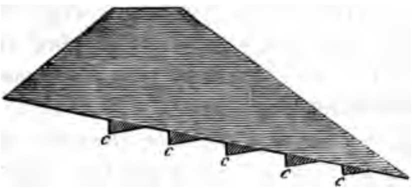
Foundations. — Experience has proved that by judicious drainage and the use of proper materials a sound bearance can be made upon almost any kind of foundation. We allude to the Liverpool and Manchester railway being carried over Chat Moss; sometimes running above (by being formed with the *moss* after it had been first properly drained), sometimes below, and sometimes on a level with the moss; an achievement which, prior to that great work, was generally considered impossible, but has since been of frequent occurrence.

Foundations are often improved by placing hurdles wound with thorns, willows, &c., upon them, providing the ground can be made to carry the embankment, but where this is large, the inferior matter is displaced for a considerable distance from the line, often causing a very heavy expenditure before a solid foundation can be obtained. The quantity of earth used at some places to form an embankment, and the extent of land elevated a considerable height by the pressure would almost appear incredible.

When an embankment is being formed upon a foundation that shrinks by the pressure, it is advisable to construct it in layers, and considerably broader than where the ground is solid, as by descending it forms the base of an embankment of far greater capacity than its *apparent* elevation. This method tends much to prevent those vast disruptions taking place during the time such embankments are subsiding, and also tends to hasten their consolidation.

Where the surface is of a sloping direction, or

ascends from the end of the embankment (as is the case after reaching the deepest part of a valley), sufficient drainage is indispensable to prevent the water descending from the high lands accumulating at the foot of the embankment; a frequent cause of inconvenience and expense. In sidling ground a proper drain ought also to be formed on the upper side, to keep the foundation dry. If this be omitted, the water forces itself underneath, frequently splitting and carrying large portions from the low side of the embankment.



Where the transverse slope is great, the lower side, to about the centre of the line, ought to be properly stepped in benches, in order to provide the embankment with a level base to stand upon as represented in the above section. These benches should be commenced near the foot of the embankment, and finished from the lower side; the produce being kept pretty uniform on the top. They ought to have a trifling descent towards the higher side to counteract the tendency of the embankment sliding laterally. Also a slope longitudinally, and in some cases cross drains

at *c c c* to carry off the surface water until being covered up by the embankment. Five benches are drawn in the preceding section, but their number should be regulated by the height of the embankment and the inclination of the transverse slope.

In crossing abrupt places, such as the sides of a ravine, the foundations ought to be carefully examined, such spots being often liable to outbursts of water. If, indeed, mounds of great magnitude are formed upon them without their being first properly drained, the pressure causes the water in escaping to mix with the earth; and experience teaches us that when retentive earths are once thoroughly saturated with water, slipping will commence, and a great length of time must elapse before consolidation is effected.

LAYERS.—Embankments of great altitude when proceeding at their full height are very subject to a constant slipping and shrinking, often of serious consequence, besides causing many stoppages to the work. This is chiefly owing to their rapid subsidence, by being deposited in such loose masses, and their aggregation being oblique. We therefore prefer such works being constructed in a series of layers, each layer being formed to the extreme breadth of the embankment, and kept as regular on the top as possible, which causes their consolidation to be more uniform. Each layer ought to proceed with a regular descent towards the tip, so that the tractive power would be equalised and the earth drawn with the same force that returns the empty wagons.

Embanking in layers also possesses peculiar advantages for facilitating delivery. Being formed to the full breadth the number of tipping places are materially increased, especially in the lower layers. Obstacles are also more easily surmounted. And in crossing over culverts or other masonry the risk of counteracting the pressure is greatly diminished, and in many situations much expense may be avoided by its adoption.

In making ordinary embankments they are generally constructed in one height only, which answers for all practical purposes. Upon an embankment, say thirty feet at formation-level, there is sufficient space for three tips, which is ample for most kinds of work.

Adjoining masonry, embankments ought to be carefully deposited and rammed in layers of about nine inches in thickness, to prevent the action of the earth whilst subsiding from injuring the work. Indeed in some situations, where they are formed upon masonry, the whole superincumbent mass should be consolidated as laid thereon.

Where the upper part of a culvert underneath an embankment is erected above the adjoining surface, a quantity of the best material ought to be firmly rammed against the exposed masonry; and, in some cases, also a few feet in depth upon the top of it, which tends greatly to prevent the subsidence of the earth proving injurious. And when crossing over such culverts with the lower layers of an embankment, it is absolutely necessary that a sufficiency of

earth be deposited on the side of the culvert opposite the approaching embankment, to counteract the pressure and prevent the masonry being disturbed.

In crossing a valley it sometimes happens that the necessary erections cannot be completed in sufficient time to allow of embanking in layers, except by delaying the earthwork for some time. To avoid this stoppage the embankment is either brought forward at its full height, or, having descended for a certain distance, it proceeds on a lower level towards the point of stoppage, occupying the base of the railway. The self-acting, or whatever kind of plane is hereafter used for conveying the earth to the bottom of the valley, has therefore necessarily to be formed by the side of this embankment, which both causes additional labour, and greatly impedes the progress of embanking. Now in such situations it would often be preferable to postpone the earthwork until the above erections are completed, or until they are so far completed as to allow the embanking to be commenced near them.

Inclined Planes. — On many works similar to the preceding the earth will have to be sent from a higher to a considerably lower level, before the embanking is commenced, in order to begin the lower layers near the bottom of the valley; and gravity being the most economical mode of transit self-acting inclined planes are therefore preferable. Where the quantity of earth to be removed is great, and there is not the necessary preponderance of weight to work the latter planes of convenient length, sta-

tionary steam power may be made available. In which case they need only have sufficient fall to cause the loaded wagons to descend, drawing a rope or chain to return them with when empty. Or these planes may also be worked double, as stated in page 71.

In forming embankments it is advisable to make them an additional width on the top to allow for their subsidence, and as they invariably become hollow on the sides whilst that is in progress, this extra width greatly assists their trimming off to the proper batter.

Should an embankment require widening, as in doubling a line, it is usual to step the slope regularly on the side before tipping the additional material, which tends to unite them together.

The expense of tipping earth is very fluctuating. In fine weather, with free earth, good plant, &c., the expense of tipping forms an inconsiderable item, but where the earth is intermixed with water the process becomes very slow and expensive. Besides, there are other incidental expenses belonging to tipping, such as the tedious task of casting a great part of the soft earth from the wagons by shovels during wet weather, when it is impracticable and dangerous to tip it. But, upon an average, about one-seventh of the average price of excavating earth (page 38), or five-eighths of a penny per cubic yard, may be stated as approximating very nearly the actual cost.

When side-cutting is resorted to, it should be

procured in some situation that its execution may not interfere with the ordinary tipping, and that the operation may be another kind of earthwork to that in progress. Barrowing is often preferable for part of the side-cutting, providing land can be obtained near the line. Varying the kinds of earthwork is a great saving of materials, and also makes the whole easier of execution, some workmen preferring one kind of employment and some another. This is of great importance in some localities and should not be overlooked.

There is a constant alternate expansion and contraction in the outer part of clayey soils, occasioned by the humidity of the air, succeeded by heat and dryness, which fractures the crust of the slopes of embankments and admits the rain to pass into the interior. In order to secure them against such influence, the slopes are soiled and sown with hayseeds, the soil being deposited on the slopes as lightly as possible.

The following useful remarks relative to soiling are extracted from the *Gardeners' Gazette*. It is a system recommended of preserving potatoes. After explaining how they should be ridged up on the outside, it proceeds as follows: — "Let neither a foot tread it nor a spade beat it, but leave the whole as light as the soil will admit of; but where the soil is naturally stiff, a greater thickness of it must be added, and the sides of the ridges to be left as steep as possible, and the lighter the soil is put on, the more frost will it keep out. The reason is obvious

enough, for when light soil is laid on steep ridges, rain never enters deeper, perhaps, than two or three inches, it being held in a kind of solution with the fine earth by capillary attraction ; or, in other words, the air in the light soil keeps the rain from sinking, consequently it runs down the sides of the ridges, and keeps the interior of the mass as dry as possible; and, of course, the frost never enters to any great depth. When the soil is trodden or otherwise made firm, the air beats out of it; every drop of rain enters, and sinks through the whole mass."

For a considerable time after embankments are formed the rain often penetrates from the *top*, but on reaching the more solid formation, it oozes out at the slopes, and hence that spongy state so often observable in the latter. So soon as these places are noticed, drains ought immediately to be carefully inserted into them, that the water may escape freely without intermixing with the earth. At the same time the greatest care should be observed to ascertain the place where the rain enters, to allow of its being well puddled to render the top, if possible, waterproof, the water also being turned off the embankment by the surface drains. Indeed whereever water is observed in slopes, means cannot be adopted too soon for its removal; and the longer it is allowed to run into the embankment and draining is deferred, the more disastrous will be the consequences, and greater the expense ultimately incurred in remedying the evil. Any person conversant with the subject is aware of the enormous cost of removing

and repairing slips, therefore too great precaution cannot be taken to prevent their occurrence.

Brushwood is often preferable for draining the slopes of embankments. It affords a good space for the passage of the water, and is not readily filled up by any loose material running therein. These kind of drains are, in general, of sufficient permanency; most of them being only required until the embankments become partly consolidated.

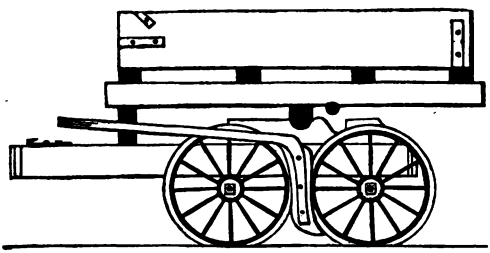
As an additional security, the slopes of some embankments are planted, the object being to cause the roots, by inserting themselves into the material, to unite it more firmly together. This is very useful in some situations.

Near the coal-works in the north, embankments are often coated with small coals to preserve the slopes, but if laid on too thick they become ignited. A rather curious case of ignition happened at the Wolverton embankment whilst making the London and Birmingham railway. "There seemed to be no end to the vagaries of this embankment; there was a portion of alum shale in it, which contained sulphuret of iron, this becoming decomposed, spontaneous combustion ensued, and one fine morning there was the novel sight of a fifty-feet embankment on fire, sleepers and all, to the great surprise of the beholders."*

EARTH-WAGONS.—The chief object to be accomplished when building earth-wagons, is, that their

* Lecount and Roscoe's Description of the London and Birmingham Railway.

construction shall be strong, firm, low, and as little complicated as possible. It is also very important that each wheel should bear an equal proportion of the load. According to the old plan the latter could not be accomplished, owing to a certain portion of the wagon being required to project over the fore-wheels, to enable it to be elevated to the necessary angle for tipping the earth. This caused too great a weight to be borne by the fore-wheels, made the wagons not travel so freely, and more apt to get off the line at any little irregularity of the rails.



A very useful kind of wagon is that termed the double-roller wagon; a drawing of which is annexed. These wagons have been very extensively used on several lines, and answer the purpose remarkably well. The axles are equidistant from the centre (see drawing), and when travelling the weight thus rests equally on all the wheels; but when in the act of tipping the wagon-body falls forward, and becomes supported upon the fore roller, the rests of which are

about one and a quarter inches lower than the rests of the other roller. The fore roller being also smaller than the hind one, and notched three-fourths of an inch deep into the upper sole, thus gives the body a drop of nearly four inches. Whilst falling from the higher to the lower rests the body assumes the proper angle of delivery, and discharges its load expeditiously; being supported meantime by the second cross piece, or sheath, coming in contact with the fore ends of the rest pieces.

The following are the dimensions and particulars of these wagons, the latter figures denoting the breadths:—

Bottom Frame. — Soles, 8 feet 6 inches long, 8 by 5 inches, and 3 feet 7 inches apart, centre and centre. The bottom frame is strengthened by two diagonal braces inside, four inches square, also by two bolts, one inch in diameter, passing through from side to side, and an iron draw-bar 5 feet 2 inches in length (the outside distance between the cross sheaths), three inches in breadth, and one-half an inch in thickness, but at the ends, where it projects nine inches beyond the sheaths, it is three-fourths of an inch in thickness. Cross sheaths, 4 feet long (the outside breadth of the soles), 6 by 5 inches. Rests for rollers, 3 feet 6 inches long, 6 by 5 inches. Wheels, 2 feet 6 inches diameter. Axles, 5 feet 6 inches long, 3 inches diameter, and three feet apart, making a distance of six inches between the wheels.

Upper Frame.—Soles, 7 feet 8 inches long, 6 by

5 inches, and 2 feet 9 inches apart, centre and centre. Length of cross pieces or sheaths, the extreme breadth of body, and 3½ by 5 inches. Hind roller, 4 feet 3 inches long, 6 by 5 inches. Fore roller, same length, 5 inches square, and journals 4¼ inches diameter. Body inside, 7 feet 3 inches long, 7 feet wide at tip end, 6 feet 8 inches at the other, and 13½ inches deep, secured at the corners as shown in the drawing. Bottom, 2 inches thick. Sides, 2½ inches thick at the bottom, 2 inches at the top, and 15½ inches deep, strengthened at the tip end by two forged iron straps (see drawing) three inches in breadth by five-eighths of an inch in thickness, and extending underneath for twelve inches in length, along the back side of the fore cross sheath, which firmly secures that end of the wagon. Height from rails to top of wagon five feet one inch. Each wagon contains thirty-three cubic feet of timber.

CHAPTER VI.

BRIDGES AND CULVERTS.

Of Foundations — Culvert Foundations — Assisting Culverts to sustain Earthen Mounds of great magnitude — Securing Culverts from the action of Mounds whilst crossing over them — Diverting Water Courses — Of Founding Culverts judiciously — Superseding Masonry by driving Close Tunnels for Water Courses in Ravines — Of Stone, Lime, Sand, and Mortar — Preparing Mortar — Grinding Lime — Preparing Mortar in Pug Mills — Grouting Masonry — Ashlar Work — Dimensions of Blocks used — Headers, Bond, &c. — Methods of Dressing Stones — Rusticated Masonry — Block and Course Work — Bricklaying — Specifying Brickwork — Radiating Bricks — Arching — Arching with Distinct Rings — Bonding Arches — Over Bridges, &c. &c.

Of all works requisite for a railway, there is none more dependant on its foundation for security than masonry. If any part prove defective after a fabric is erected, it generally causes a derangement to take place throughout the whole, and should that be once effected, it is almost impossible to restore the original stability.

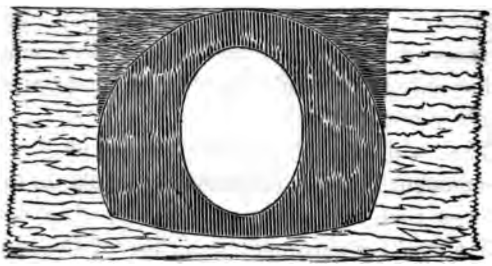
In some instances, foundations, superior to piled ones, have been obtained by displacing the inferior material to a greater width than the intended structure, and to the full depth thereof, the vacuity being afterwards filled with rubble stone to the required height for the foundation. Indeed, wherever soils are weak, it is advisable to cut an extra width behind the intended masonry, and fill the spaces with hard material as the erections are advanced.

When preparing culvert foundations they are very liable to be filled with water, and consequently their sides apt to be thrown down, if cut perpendicularly, and it being so essential to have them thus executed, or nearly so, when they are to be of considerable length, we would recommend them to be executed in portions, never proceeding far in advance of the masonry with the full depth. But, to expedite the work, the upper parts might be executed any convenient length, depositing the produce on that side of the culvert opposite to the approaching embankment. By operating in this manner, the sides of a foundation are sooner supported by the masonry; the size of the excavation is also comparatively diminished, which reduces the risk and expenses of pumping water and removing mud, by having only to contend with such, in that particular length in operation.

When culverts are to be crossed by a heavy embankment, it is sometimes advisable to found them so that the crown of the arch shall not be higher than the surrounding surface of the ground. By thus placing them, and preparing the sides of the foundation as described in the preceding paragraph, the adjoining ground materially assists to sustain the embankment, which would otherwise have to be borne exclusively by the masonry. This method also tends materially to prevent the work being injured when passing over it with embankments, and also during the subsiding of the earth.

Great care is also necessary in choosing the site

of such culverts as have much pressure to sustain. It often happens that the mere diversion of a brook will enable a culvert to be securely founded in rising ground, making it almost impossible to disturb it by an approaching embankment. And in ravines, by altering their direction a little, they may often be founded, having a substantial barrier behind their central part to support them, and opposite, of course, to where the pressure of the approaching embankment is greatest. By taking these precautions much labour in wheeling and punning earth to counteract the pressure may be avoided.



In circular culverts we have frequently observed the masonry of the upper part of the arches seriously injured by the superincumbent earth, especially underneath the central part of embankments, a circumstance obviously caused by the pressure being unequal. Also serious defects arising from inverts having too little curvature; indeed, so much so, that

in some cases inverts have risen up in the middle, which allowed the bottom part of the side-walls to be forced in. We were thus induced to believe that by making those erections of an oval or egg shape, similar to that represented in the opposite section, the unequal pressure would be materially diminished, if not entirely avoided. We therefore adopted this plan underneath some embankments of great altitude, and the results were in accordance with our anticipations.

In crossing a valley it sometimes happens that by diverting a water-course judiciously masonry may be altogether dispensed with. This ingenious plan was successfully carried into execution three miles south of Borrow Bridge whilst making the Lancaster and Carlisle Railway. Instead of the ordinary method of providing a passage for the water by masonry, the brook-course was diverted a little, and a close tunnel driven in, and nearly parallel, to the side of the ravine for one hundred and twelve yards in length, through which the brook was turned, the old course being afterwards filled up solid by the embankment. This tunnel is driven through hard blue rock and shale, and in the central part has a roof of nearly sixty feet in depth to support the embankment. The sides of the ravine are very steep, particularly the south one, through which the tunnel is driven. The embankment at this place is ninety-five feet in height, and of course had masonry been adopted it must have been of great strength to sustain such extraordinary pressure. Where a tunnel

can be driven in this manner it makes an excellent passage for water, not only being free from the danger of being crushed by an embankment, but also considerably less expensive than masonry, exclusive of the expense of wheeling and punning earth often attending the latter.

Of Stone. — In masonry the most durable materials should be employed, possessing the qualities of hardness, tenacity, &c., with the property of resisting the decomposing effects of water and the atmosphere. The decay and destruction of stone in buildings, are attributable partly to the chemical changes effected by decomposition in the stone itself, and partly to the action of frost producing disunion of parts.

"Decomposition takes place, when the stone contains parts that are more or less soluble in water, or which enter into combination with the oxygen of the air or acids in water. Iron, in different states of oxydation, and in different proportions, enters into the composition of almost all stones, and is frequently an important agent in their decomposition. When stones contain pure iron, it rusts or oxydates, and expands so as to burst the parts asunder. The iron absorbing oxygen and carbonic acid from the air, the presence of moisture accelerates this kind of decomposition and it is always still further hastened by increase of temperature.

"Disintegration is the separation of the parts of stones by mechanical action, the chief cause is the congelation of water in the minute pores and fissures of stones, which bursts them open, or separates small

parts, according as the structure is slaty, or irregularly granulated. The south sides of buildings, in northern climates, are most subject to fail from this cause; for the surface is often thawed and filled with wet in the sunny part of the day, and frozen again at night. This repeated operation of freezing is very injurious to the piers of bridges, and other works exposed alternately to water and frost."*

MORTAR. — The quantity of powdered lime yielded from a fixed measure of well-burnt lime fluctuates considerably, although the stone may have been quarried from the same mine. The quality of both lime and sand is also variable; therefore no fixed ratio can with propriety be said to constitute the best mortar.

Bishop Watson, we believe, proved by experiments, that upon an average, every ton of limestone produced eleven and a quarter hundred-weight of quick-lime, weighed before it was cold; but that, when exposed to the air, it increased in weight daily, at the rate of a hundred-weight per ton, for the first five or six days after it was drawn from the kiln; owing to its gradual absorption of carbonic acid.

When slaking lime, a small portion only ought to be in operation at the same time; and when wetted, immediately covered with sand, observing that the whole operation should be as rapid as possible. This method prevents the gas, or strength of the lime, from escaping, and by the sand and lime being thus

* The above, and the two quotations in the following article (Mortar), are extracted from Kelly's "Practical Masonry."

mixed, it tends greatly to facilitate the labour of incorporating them together, when being reduced to the consistency of mortar.

"It is universally allowed that the hardness of mortar depends on the crystallization of the lime round the other materials which are mixed with it; thus uniting the whole mass into one solid substance. But, if a portion of the materials used be clay, or any other friable substance, it must be evident that as these friable substances are not changed in one single particular, by the process of being mixed up with lime and water, the mortar, of which they form a proportion, will consequently be more or less of a friable nature, in proportion to the quantity of friable substances used in the composition of the mortar. On the other hand, if mortar be composed of lime and good sand only, as the sand is a stony substance and not in the least friable, and as the lime, by perfect crystallization, becomes likewise of a stony nature, it must follow that a mass of mortar composed of these two stony substances, will itself be a hard, solid, unfriable substance." It is therefore obvious that if the matter interposed between the crystals of the lime be composed of soil, the scrapings of roads, or any other brittle substance, the mortar will necessarily be very imperfect and friable. Consequently these substances ought to be rejected, and clean sharp sand introduced.

"When lime has been long kept in heaps, or untight casks, it is reduced to the state of chalk, and becomes every day less capable of being made into

good mortar; because, as the goodness or durability of the mortar depends on the crystallization of the lime, and, as experiments have proved that lime, when reduced to this chalk-like state, is always incapable of perfect crystallization, it must follow that as lime in this state never becomes crystallized, the mortar of which it forms the most indispensable part will necessarily be very imperfect; that is to say, it will never become a solid stony substance, a circumstance absolutely required in the formation of good durable mortar."

In some places the lime is not slaked with water, but ground to a powder underneath a circular stone roller erected for that purpose, moving about a centre. This plan improves the setting qualities of some limes very considerably.

Another method of preparing mortar is the mixing it in a soft state, in what is termed a pug mill, the lime being put therein when fresh, in a powdered state, intermixed with sand. These mills consist of an upright circular casing, inside of which a perpendicular shaft works, having horizontal arms placed at different heights, projecting at right angles, to it, and upright iron knives fixed in the latter at suitable distances from the centre, and by their revolution the mortar becomes thoroughly incorporated. Where steam power is available, and those mills can be conveniently attached thereto, they are used to great advantage

Grouting is very essential for procuring solid masonry. The lime, when quick and hot, should be

mixed with water to a proper consistency, and poured upon each course, which renders solid all the interstices, and thus unites the whole mass together. It would appear that grouting was much practiced by the Romans, the efficacy of which is observable at the present time, many of their works having endured for so many centuries.

ASHLAR WORK. — As all masonry, but especially that of an inferior description, gains additional strength, and is better adapted for resisting pressure when the mortar has become properly set, it is advisable to have the several structures completed in sufficient time to allow this to take place.

The dimensions of the blocks used in building should be in proportion to the thickness of the work wherein they are to be used, and so disposed as to cause each joint to be as near the middle of the stones underneath it as practicable. A sufficient number of headers should also be introduced, uniformly distributed throughout the whole work, so that by the stones properly overlapping one another and being thus secured, the whole may be thoroughly connected together.

Care should be taken to avoid either short stretchers or those of too great length, as they prevent the regular connection of others. They should not be much shorter than one and a half, nor yet much longer than three times their thickness. The former often causes a stone to be laid upon the middle of a stretcher, and in the succeeding course another stretcher is obliged to be laid across it and make

bond with the adjoining stones, thus forming no face-bond with the short one. These stretchers are very apt to be broken by their additional length, and also from the difficulty of giving the short stone its due proportion of the pressure.

Particular attention is necessary whilst dressing the stones in order to make the surfaces as regular as possible, avoid any twisting in their beds and joints, and at the same time *not* to present a perfect smooth surface. Where mortar is good and the beds carefully indented a great increase of strength is obtained, the mortar forming a kind of dowelled work with the upper and under beds, and defying a great pressure to push a stone of its bed when thus fixed.

In dressing stones of great breadth, extra draughts (narrow strips coinciding with a straight-edge or rule used for that purpose) should be worked along and across their beds, but where narrower, diagonal draughts worked across them will suffice. By preparing the stones in this manner their beds may be rendered perfectly straight and level. This secures to each bed an uniform bearance for the whole area, and also tends greatly to prevent the stone from *flushing* (becoming fractured at and near the joints) Flushing, however, is often avoided by rusticating the joints, embracing at the same time an improvement in the appearance of the masonry.

Block-and-course work is a species of serviceable masonry much used in the building of occupation bridges, culverts, walls, &c. It is externally com-

posed of stone in courses of from six to fourteen inches in thickness (but the sizes vary materially in different districts), nine to twenty inches in breadth, and in lengths of from nine to twenty-four inches and upwards, and connected with the interior of the wall by bond-stones of similar thickness. The interior and back part are composed of common rubble, which should be well connected together, and also to the stones in front, and the whole breadth of the wall carried up regularly.

BRICKLAYING. — The surfaces of bricks are very subject to be covered with loose earthy particles, which prevent the mortar from adhering; and in order to free them from such impurities they should either be put in water, or have quantities of it thrown upon them prior to their being used. Additional strength is thus obtained, for, by cleansing the bricks, the mortar adheres firmly, and unites the whole mass together. In arching, wetting the bricks is not only essential, but also tends greatly to facilitate their laying, especially in the central part, where the courses* become nearly vertical.

Brickwork should be made of so many bricks in breadth, and not specified in feet. The back of a battering wall ought to be kept in parallel planes with its face, reducing it regularly by scarcements at the back; and walls tapering longitudinally ought to have their breadth reduced in the same manner,

* The whole of the bricks in a layer of the thickness of one brick constitute a 'course' of brickwork. The same will apply to a wall whether the bricks are laid level or otherwise.

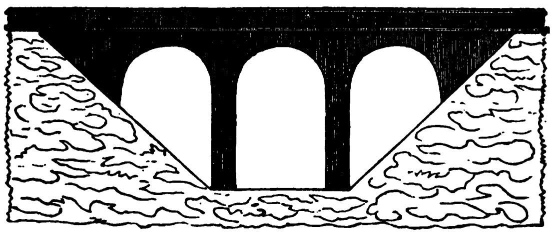
in order to prevent refuse pieces of bricks being inserted in every course.

A great defect in the laying of bricks is the omission to mortar the joints of the outside bricks to their full breadth, and the headers to their full length, an omission which allows the wet and frost to penetrate into the interior of the wall, to the great injury of the structure.

It is almost superfluous to say that bricks forming the frustum of a wedge, usually termed radiating bricks, are the best adapted for constructing arches; common bricks, having their beds in parallel planes, cannot strictly be considered as constituting any part of arches. But there being generally a great discrepancy in the thickness of common bricks, by carefully selecting them, and procuring bricks from different kilns, we obtain them of various thicknesses; hence by laying the thin bricks at the intrados, the thicker ones behind, and those of the greatest thickness at the extrados, arches of great strength and durability are obtained without using additional mortar. This method is commonly resorted to in practice, and answers the purpose even under embankments of great altitude.

But where arches are of small diameter the above method cannot be adopted, and if radiating bricks are not used the arches are either composed of distinct rings of brickwork, or extra rows of bricks are introduced into the interior and back part of the arches, and bonded together at intervals where any two rings of brickwork happen to coincide. When

thus connecting two rings together, especially should many courses intervene between the places where they are bonded, it will sometimes be advisable to bond them together with two single rows of headers, laid immediately upon each other, the upper headers crossing those underneath, longitudinally, half the breadth of a brick, as the thickness of one brick is often inadequate to bond two rings securely; for, when the arch becomes loaded, a trifling deviation of form takes place, which has a great tendency to snap in two a single course of bond bricks at those places.



In arching with distinct rings of brickwork, it is indispensably necessary to use every precaution, such as avoiding extra thickness of mortar, irregular keying, &c. to give to each distinct ring an equal amount of pressure, so that they may act in unison together, and, comparatively speaking, constitute only *one* ring.

In erecting common over bridges perhaps the best

method is to adopt the lower kind of arches of an elliptical form, rising about nine feet in thirty feet span, in order to obtain additional height above the springing. When these bridges are erected in deep cutting, we prefer building them with three arches, which greatly decreases the height and pressure of the wing walls, as represented in the elevation. And in building them it is a good rule to observe that the height of the arches ought not to exceed that of the piers, but where the latter are of great elevation semicircular arches may be introduced to advantage.

CHAPTER VII.

FENCING.

Of Planting — Proper Season for Planting Quicks — Methods of Planting and Cleansing – Setting Fences — Proper Age of Quicks for Planting — Favourable Soils – How Prepared — Plants require Attention and Protection — Manuring Quicks — Pruning Hedges — Their Form – Cutting and Warping Hedges — Willow and other Hedges — Planting Quicks — Evil Effects of Injudicious Pruning — Fence Railing — Posts, Rails, &c. — Dry-Walls — Modes of Building — Copings — Foundations – Procuring Materials, &c. &c.

THE appearance of some lines is very much improved by being partially planted at some places. In fact many small patches of land, and the foot of embankments, by being planted with useful timber, might not only be rendered valuable, but also improve the general appearance of the line. Good hedges also greatly contribute to the latter.

Advantage ought to be taken during open seasons, say from October to about the middle of March, to plant the quicks before the sap rises. Young hedges ought also to be kept clean; no weeds being suffered to grow amongst them, especially for the first three or four years. Neither should quicks be planted until the earthworks are completed, as they are apt to be trodden down and destroyed whilst such works are in operation.

Along the tops of cuttings quicks should be

planted near the surface to afford their roots additional moisture, but at the foot of embankments they ought to be a little elevated as a preventive of excessive damp during winter, and planted a sufficient distance from the fence-railing to prevent their being destroyed by cattle, sheep, &c. Quicks, three years transplanted, are generally preferred. They certainly are more costly in the first instance than younger ones, but eventually become by far the cheapest, and also form a hedge much sooner and stronger.

The following particulars relative to hedges are extracted from a work entitled *Useful and Ornamental Planting,* published under the superintendence of the Society for the Diffusion of Useful Knowledge. "There are several kinds of *quick* fences, which differ merely in the mode of planting the thorns *(Cratægus oxycanthus.)* The white thorn is a plant much checked in growth by every other, whether herbaceous weed or shrub, that mingles with it in the soil. It delights in a strong loam, on poor sands, or damp clay; and requires great attention in the preparation of the soil, in the selection of the plants, and in the mode of planting. It must be carefully protected from cattle and rabbits, which, by nipping of the tender first shoots of the spring, seriously injure its growth, and defeat the intention of raising an effective fence at the least cost, and in the shortest space of time.

On poor sandy soils, the depth of earth for the reception of the plants should be made as great as possible, and they should be placed on the top of

the bank. Manure of rotten leaves, compost of marl or clay, and dung, ashes, or any substance that will enrich the line of planting, should be dug in if possible for the encouragement of the roots of the young quick. Where the soil is damp and clayey, planting the thorns on the face of the bank is the best practice. The ground should be perfectly clean, or the cost of weeding it afterwards will be considerable, and the fence will make little progress if it do not fail altogether.

The cost of the manure above alluded to will be amply repaid by the more rapid growth of the quick, saving much of the expense of weeding, and of filling up blanks and gaps in the hedge, which always accompanies the rearing of this kind of fence on poor or badly prepared ungenial land. The size of the plants deserves particular attention, for by planting strong three-year-old transplanted thorns, the success of the fence is secured, and the distance of time for its completion shortened by three years.

In the management of the hedges when planted, weeding is most essential, for if coarse grass or rampant weeds are suffered to mingle with the lower branches and foliage of the quick, the injury is very considerable. The top of the hedge should be kept level from the first cutting, until the plants have attained to the desired height. The sides of the hedge ought to be kept also of an even surface; by shortening the side branches every year to within an inch, more or less, of the preceding year's wood,

the bottom of the hedge is maintained equally thick and impenetrable with the upper portion. The most generally approved form of a hedge is that of the *hog's mane;* however, if the soil has been properly prepared, the plants selected of the largest size, and the keeping clear of weeds, and most judicious mode of pruning persevered in, the hedge will flourish in every shape.

By keeping the top of a hedge level, it is not meant that all the plants should be shortened in the leading shoot of the stem, but only those which overtop their thin neighbours. If this be properly attended to, the evil effects which follow the practice of shortening without exception the leading shoots of every plant of the hedge will be avoided, as well as those which occur when the upright growth of any plant is left uncontrolled until it reach to the desired height.

Where a hedge has been neglected, is overgrown and irregular, the best mode is to cut it down level with the soil, and then to dig the earth about the stumps, inserting plants of strong quick in the gaps where they occur. It may happen that the fence cannot be dispensed with during the time the young shoots from the old roots require to renew the fence. In this case, the mode of cutting a fourth part of the stems to the desired height, and another fourth part a few inches from the ground, and warping the remainder with these is found a useful practice.

Besides the white thorn or quick, and the furze (*Ulex Europæus*), there are many other shrubs

which may be planted under certain circumstances with effect as fences. In exposed cold soils, the Huntingdon willow, beech, birch, and alder, may be used with advantage." In damp situations, along the foot of embankments, common willows are often planted with advantage, and soon form a good fence.

The subjoined extracts are selected from *British Husbandry*, a useful work, published by the same excellent institution. "In the month of October, it has been before observed, the season for planting will commence, and this work may be carried forward during the winter, or until the middle of March. —Mark out the intended line of the ditch, nine inches apart from the line where the quick-wood is intended to shoot up. Take a spit of earth nine inches wide and three inches deep from out of the intended ditch, and invert it upon this space—lay it neat and level, cut off the tops of the thorns two inches above the root, and, if needful, shorten the tap-root. Place the plants, so cut, four inches apart between plant and plant, in such a manner that the tops may appear exactly above this 'cooping'; cover the roots first with another spit of earth from the surface of the intended ditch, and then sufficiently with next best soil from the same place; but do not overload the roots with earth."

"A hedge planted in this manner requires, in order to render it a fence in the shortest time, a little judicious pruning. It should be considered that the main strength of a hedge consists in the *unyielding stoutness of the principal stems;* and to

have these of the requisite strength, they should only be moderately pruned on each side, cutting out the strongest branches, which act as rivals to the stem, but *never topped* until they have acquired a diametric bulk of one inch at the height of three and a half feet from the ground. When this strength of stems is obtained, the hedge is complete as a fence against all kinds of cattle which are not high leapers, and will so continue for many years, with no other labour than what may be annually given by a keen trimming-hook, or by shears, to keep it from uselessly spreading.

Many fine young hedges are ruined by being too frequently headed down at different heights in their youth. It should be remembered that every individual thorn in a hedge is like a single tree planted on a lawn, both of which are wished to rise into full strength and stature as soon as possible; but this result can surely not be obtained by repeatedly cutting off the head of either one or the other. When a sufficient number of stems can be once made to rise from the bottom of the quick either in the first or second year, the leaders should never be cropped till they have gained the requisite strength; for by so doing, a thick mass of spray is produced, which, to the eye, appears a barrier, and, for a short time, a fence against sheep; but not against a mounted sportsman, who will trample it down, or against heavy cattle, which, in browsing, press through it. Besides, by heading down before the stems are sufficiently strong, the hedge becomes

top-heavy from the abundance of spray, which shades, and eventually kills that below, rendering the stems naked at bottom; through which pigs, or lambs, or Welsh sheep soon make thoroughfares."

FENCE RAILING.—Various forms of fencing are resorted to, but that most commonly used is composed of either oak or larch, four rails in height. The rails should not be in longer lengths than about eight feet, unless they are supported by additional posts. The holes for receiving the posts, ought not to be less than two feet in depth from the surface, and the latter firmly punned when fixed in the ground, their thicker ends being placed downwards. Good posts are usually about sixteen inches in girth at the smaller end, and provided with four holes to receive the ends of the rails; and the rails about ten inches in girth.

DRY-WALLS.—This kind of fencing is very much used in some districts. The walls are usually built without mortar, except for the coping, and they make a very good fence; being about six feet in height, three feet thick at the bottom, fourteen inches at the top, and bonded together with three rows of throughs overhanging each side of the wall. Care should be taken that the stones are properly overlapped inside, and well crossed on each face to prevent straight joints occurring, the filling made completely solid inside, and all large sloping stones carefully laid in the foundation, sloping towards the upper side if used on sidling ground.

The coping of fence-walls is also of great impor-

tance. The simplest and best kind being that composed of flat stones placed edgewise, and so arranged that a high and low stone come together alternately, making the top as irregular as possible. These coping stones should be set in good mortar overhanging the wall, and be properly wedged together by chips of stone, until they become firm and solid.

Where the surface is much sloped in the direction of the wall, the foundations ought to be regularly stepped in benches; and where it slopes much in the contrary direction, they ought to be cut with a small descent towards the higher side, a little additional batter being also given to the lower face, to counteract the tendency of the walls moving downwards.

In rock cuttings the best stone ought to be selected, and carefully deposited in some convenient situation, whilst they are in progress, for building the fence walls; that used along the cuttings being removed to the surface by horse-runs, barrow-roads, scaffolds, &c., but opposite the embankments, of course, greater facilities exist. By attending to the above, good fences may often be erected very economically.

CHAPTER VIII.

PERMANENT WAYLAYING.

Of Malleable and Cast-iron Rails — Birkenshaw's Patent Rails – Comparative Weights of each kind of Rail — Advantages, &c., of Malleable-iron — Comparative wear of Malleable and Cast-iron both in Wheels and Rails, from actual practice — Permanent Roads — Adjusting Formation-Level — Of Ballast and Ballasting — Drainage, &c. — Surface Draining — Of Stone Blocks, &c. — Chairing Blocks — Preparing Ballast for Block Roads — Setting Blocks and mode of Consolidating them — Setting Blocks at right angles; obliquely; alternately square and oblique, &c. — Of Laying Roads on Transverse Sleepers — Curved Roads — Level Crossings, &c. — Improved Gates for Level Crossings — Mode of fixing the Rails and Chairs on the Liverpool and Manchester Railway — Mr. Losh's plan — Parallel Rails and mode of Fixing — Chairs with Iron Keys, &c. — The Improved H Rails — Compressed Oak Keys — Chairs for Oak Keys — Fixing the Improved H Rail with Oak Keys on the Lancaster and Carlisle Railway — Mode of Fixing Rails with Double Oak Keys, as used on the Hull and Selby Railway — Of Railways laid on Continuous Bearings — Materials, &c. — Mode of fixing and connecting the Rails, Longitudinal and other Timbers on the Great Western Railway — On the Croydon Railway — On the Newcastle-on-Tyne and North Shields Railway — Mackintosh's Patent Vulcanised Indian Rubber; Patent Felt, &c. — Comparison of Guages on different Lines, &c., &c.

AFTER cast-iron rails had been in use for some time another great improvement took place, that of malleable-iron rails. At their introduction, however, a great prejudice existed, namely, that from their soft and fibrous texture they would be liable to exfoliate and wear fast away, &c.

In a report of Mr. Chapman, the following passage favourable to cast-iron occurs:—"The railway may

either be formed of cast-iron or malleable-iron. The latter may be somewhat less expensive, and has been found eligible in rolley-ways below ground, in which the weight on each wheel is not considerable: but, above ground, with heavy wagons, their utility, or rather their duration, is not likely to be so great as rails of cast-iron of due strength; because with heavy carriages, and case-hardened wheels, (which are much in use except for locomotive engines, as it would diminish their adhesion to the way), the following effect is produced from the softness of malleable-iron, viz., the rails formed of it being drawn out between rollers, and consequently fibrous, the great wheels, rolling on those ways, expand their upper surface, and at length causes it to separate in thin laminæ. The injury from oxydation is comparatively small."*

This report, as might naturally be expected, drew a reply from one of the advocates of malleable-iron, and accordingly we find Mr. Longridge, of the Bedlington Iron-works, warmly defending its utility. He also produced the annexed letter from Mr. Thompson, Lord Carlisle's agent at Tindale Fell, Cumberland, where malleable-iron rails had been in use for sixteen years:—"The whole of the wrought-iron which has been used from twelve to sixteen years, appears to be very little worse. The cast-iron is certainly much worse, and subject to considerable breakage, although the rails are about double the

* Report relative to a communication between Newcastle-upon-Tyne and Carlisle.

weight of the malleable-iron rails. The waggons used to carry near a Newcastle chaldron, namely, fifty-three cwt."*

The following is the report of Mr. George Stephenson on the subject. It showed very clearly at the time it was written the superiority of malleable iron, which has since been fully corroborated :—

"The great object in the construction of a rail-road, is that the materials shall be such as to allow the greatest quantity of work to be done at the least possible expenditure; and that the materials also be of the most durable nature. In my opinion Birkenshaw's patent wrought-iron rail possesses these advantages in a higher degree than any other. It is evident that such rails can at present be made cheaper than those that are cast, as the former require to be only half the weight of the latter, to afford the same security to the carriages passing over them, while the price of the one material is by no means double that of the other. Wrought-iron rails, of the same expense, admit of a greater variety in the performance of the work, and employment of the power upon them, as the speed of the carriages may be increased to a very high velocity without any risk of breaking the rails; their toughness rendering them less liable to fracture from an impulsive force, or a sudden jerk. To have the same advantages in this respect, the cast-iron rails would require to be of enormous weight, increasing, of course, the original cost."

* Newcastle Courant, Dec. 18th, 1824.

From their construction, the malleable-iron rails are much more easily kept in order. One bar is made long enough to extend over several blocks; hence there are fewer joints, or joinings, and the blocks and pedestals assist in keeping each other in their proper places.

On this account, also, carriages will pass along such rails more smoothly than they can do on those that are of cast-iron.

The malleable-iron rails are more constant and regular in their decay, by the contact and pressure of the wheel; but they will, on the whole, last longer than cast-iron rails. It has been said by some engineers, that the wrought-iron exfoliate, or separate, in their laminæ, on that part which is exposed to the pressure of the wheel. This I pointedly deny, as I have closely examined rails which have been in use for many years, with a heavy tonnage passing along them, and on no part are such exfoliations to be seen. Pressure alone will be more destructive to the cohesive texture of cast-iron than to that of wrought-iron. The true elasticity of cast-iron is greater than that of malleable iron; *i. e.*, the former can, by a distending power, be drawn through a greater space, without permanent alteration of the form; but it admits of very little change of form without producing total fracture. Malleable-iron, however, is susceptible of a very great change of form, without diminution of its cohesive power; the difference is yet more remarkable, when the two substances are exposed to

pressure, for a force which, in consequence of its crystalline texture, would crumble down the cast-iron, would merely extend or flatten the other, and thus increase its power to resist the pressure. We may say, then, that the property of being extensible, or malleable, destroys the possibility of exfoliation as long as the substance remains unchanged by chemical agency. A remarkable difference as to uniformity of condition or texture in the two bodies, produces a corresponding want of uniformity in the effects of the rubbing or friction of the wheel. All the particles of malleable-iron, whether internal or superficial, resist separation from the adjoining particles with nearly equal forces. Cast-iron, however, as is the case with other bodies of similar formation, is both harder and tougher in the exterior part of a bar than it is in the interior. This, doubtless, arises from the more rapid cooling of the exterior. The consequence is, that when the upper surface of a cast-iron rail is ground away by the friction of the wheel, the decay becomes very rapid.

The effects of the atmosphere in the two cases are not so different as to be of much moment. On no malleable-iron railway has oxydization or rusting taken place to any important extent.

I am inclined to think that this effect is prevented on the bearing surfaces of much used railways, by the pressure upon them. To account for their extraordinary freedom from rust, it is almost necessary to suppose, that some diminution takes place in the chemical affinity of the iron for the oxygen

or carbonic acid. The continual smoothness in which they are kept, by the contact of the wheels, has the usual effect of polish, in presenting to the destroying influence a smaller surface to act upon. The black oxyde, or crust, which always remains upon rolled iron, appears to act as a defence against the oxydizing power of the atmosphere, or water. This is the reason why the rail does not rust on its sides."

A great difference in the tendency to rust has been remarked between malleable-iron rails standing upright or laid carelessly upon the ground, and when fixed, subject to the continual motion of carriages; the former continually throwing off scales of oxydated iron, while the latter is scarcely at all affected.

Since the date of Mr. Stephenson's report (now a considerable period) both kinds of material has been to a very great extent developed, and the result is decidedly favourable to the adoption of malleable-iron. It has also been clearly demonstrated that the wear is greatest upon cast-iron both by the action of locomotive engine-wheels (made of the two kinds of material); and by minutely weighing the rails, after being subject to certain weights passing along them for a specified time.

Upon the Killingworth railway, common cast-iron wheels were originally used for the locomotive engines, but were at length superseded by wrought-iron ones. The following extract* shows their relative

* "Treatise on Railroads" by Mr. Nicholas Wood, in which will be found a mass of useful information on the subject of railways and carriages, including numerous accounts of original experiments.

wear. "The average wear of the cast-iron wheels was above half an inch in nine months; and with the wrought-iron tire, the wear of one pair of wheels has been one-fourth of an inch in three years, and with three other engines, one-eighth of an inch in twelve months; making the wear at least as five to one in favour of wrought-iron. The actual wear of the rails will not be to the same extent as this, as the engine-wheels sometimes slip round, or slide upon the rails in bad weather. The wear of the wheels of the common carriages will not be so much, for the same reasons; but although it should be observed, that from this we ought not to deduce the actual duration of wrought-iron rails, as, their surfaces being narrower than the wheels, the wear will be, perhaps, more than proportionably greater; yet the relative wear should, however, remain the same."

Subjoined is the comparative loss of weight of wrought and cast-iron rails, upon the Stockton and Darlington railway; the particulars being given as obtained by the engineer, Mr. Storey.

Malleable-iron Rails, fifteen feet long, over which locomotive engines pass, weighing from eight to eleven tons: wagons and their loads, four tons each.

86,000 tons passed over in a year, exclusive of engine and wagons.

Weight of rail, 1 cwt. 24½ lbs.
Loss of weight in 12 months, 8 oz.

Cast-iron Rails, four feet long, over which wag-

ons only pass, weighing four tons each, when loaded.

86,000 tons passed over in a year, exclusive of wagons.

Weight of rail, 63 lbs.
Loss of weight in 12 months, 8 oz.

The loss of weight in malleable-iron rails, when wagons *only* passed over, was, in the same period, eight ounces for fifteen feet length; the same quantity of goods, 86,000 tons.

BALLASTING.—It is almost superfluous to say how desirable it is to allow embankments to subside, whenever practicable, before commencing ballasting for the permanent road, as those formed during the different stages of the work are generally required to be laid permanently as each length is completed, both to release temporary materials and to facilitate the transmission of the remainder; also to equalise the work by preventing too much permanent road being in hand at once: and embankments formed during the latter part of the time are usually required to be completed as speedily as possible, in order to open the line to the public.

The formation-level having been carefully adjusted, and upon the higher embankments a little above the proper height, the next operation is the covering it with a layer of broken stone, the roundest part selected from gravel, or other open substance, upon which is laid a coating of small coals, ashes, gravel,

&c., or whatever kind of good ballasting-material the district will afford. This layer is first formed to the level or a little above the under side of the blocks or sleepers, and after the permanent road is laid and adjusted the remainder of the ballast to within about three inches of the top of the rails is completed. The thickness of ballast is generally about two feet, but upon embankments less is necessary for laying the permanent road in the first instance, as new lines frequently require additional ballast to maintain the proper elevation.

Where sand or other fine ballast is used on embankments in exposed situations, soiling it over to within about two feet of the rails is a good method of preventing its being injured by the wind.

Small coals or ashes are decidedly the best materials for ballasting, they considerably diminish the expense of maintenance, owing to their being so expeditiously packed solid underneath the blocks and sleepers, the comparative ease with which they are displaced to re-adjust the same, and their peculiar permanency when once properly consolidated.

DRAINAGE.—Longitudinal rubble drains along the centre of a line are very essential for keeping the foundation dry and firm, providing the ballast is *all* composed of fine material, or in situations where the foundations are damp and spongy underneath. In the latter case it is advisable to insert them a little below the foundation of the ballasting, having cross-drains one-half the breadth of the line intersecting

the former right and left alternately, and communicating with the side-ditches.

Permanent roads should be provided with proper surface-drains to carry off the water effectually in short lengths, and never allow it to accumulate. They should also be furnished with a cross surface-drain, one-half their breadth, about every eight feet, carried through underneath both rails to the centre: and upon all steep inclinations very great care should be observed that on no account whatever ought the water to be allowed to run further than one length of rails, say sixteen feet, before being turned out by a cross-drain; and to effect which, the side of the latter ought to be kept pretty *high* on the *lower side* of the railway. If water be allowed to accumulate in the centre, during storms and wet weather it is apt to flow a considerable distance along the centre, and when escaping, if upon an embankment, frequently causes a slip to take place in the slope, which might easily prove of serious consequence. This is especially to be attended to during the first three or four years after opening a line.

The side-drainage of excavations ought to be frequently cleansed of all extraneous matter, particularly if they are of slight inclination, or their length be considerable without an outlet, and they should be kept at least six inches below the foundation of the ballasting.

Stone Blocks.—On account of the immense pressure which stone blocks have to sustain from heavy trains, they ought to be composed of a hard

uniform texture, to prevent either breakage or the chairs working loose. Many kinds of laminated stone too are objectionable owing to the stone splitting horizontally whilst fixing or re-adjusting the blocks. Stone blocks are generally used about two feet square and from eleven to thirteen inches in thickness; sometimes a little oblong, but should always be kept pretty uniform in size, and the largest ought to be selected for the joints.

In chairing blocks it is of great importance that the seats should be rendered perfectly straight and level to allow the chairs to stand firmly upon them. If the chair does not rest upon the *whole* of the under surface its proper bearing is destroyed, a circumstance which soon operates very injuriously against the smoothness of a block road.

The most approved system of fixing the chairs to the blocks is to drill two holes parallel into each block six inches deep and about two inches in diameter, the distance between their centres corresponding with the distance between the centres of the spike-holes in the chairs. Into these holes two bored oak plugs are driven which fill the holes. A piece of felt is then laid under the chair, and two iron spikes three-quarters of an inch in diameter and six inches in length are driven therein, and thus a great strength and solidity is obtained.

As blocks are often of different thicknesses it is advisable to form the ballast to the proper height of the thin ones, and remove a little for those which are thicker whilst setting them. If blocks are set on

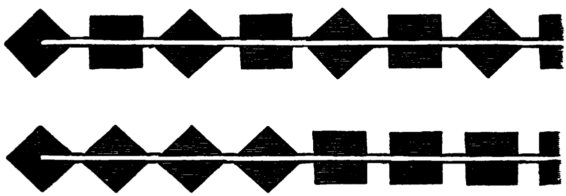
broken stone ballast a few inches of gravel or other fine ballast ought to be laid immediately underneath them to mix and fill up the interstices between the stones, and every means should be used to render their foundation as firm and solid as possible.

Each block should be set firmly with the lever, by being lifted up and quickly jerked down upon its bed, and this operation repeated until the ballast is properly consolidated and the block does not yield from the blow. If an additional thickness of ballast is necessary the block must be removed and the ballast properly levelled, and then the above operation repeated until the block becomes firmly fixed. No block ought to be packed up or beaten otherwise than with the lever, as their consolidation is made more perfect and accomplished with less expense by using it in the first instance than in repairing the road hereafter.

Where blocks with three feet bearings (and many kinds of rails are so formed that the blocks must be laid at these equal distances) are set at right-angles with a line and require opening out to be re-adjusted, it is extremely difficult to re-pack and consolidate the ballast underneath them. If the blocks be two feet square they are only one foot asunder, and hence the above difficulty. To obviate this they are sometimes fixed diagonally, which causes their opposite corners to stretch along the line, and thus renders every side and underneath them available. Now by setting blocks obliquely a comparatively additional breadth of bearing surface is obtained, but their ex-

tremities where the action and pressure is greatest are reduced to mere points as exhibited by the left side of the lower line of blocks in the annexed diagram. The greatest breadth of stone is thus deposited underneath the rails where it is subject to the least action and pressure, while each block laid at right-angles presents two feet of bearing surface at each extremity to sustain both action and pressure.

In laying the above kind of road we prefer a combination of both modes in order to avoid the defectiveness at the extremities of the oblique ones, to



obtain the facility they afford for packing, and to preserve as much bearing surface as possible at the extremities by retaining those at right-angles. We suggest, therefore, that with twelve-feet rails and three-feet bearings the blocks should be laid alternately square and oblique as represented by the upper line of blocks in the engraving; and fifteen-feet rails with the two centre blocks at right-angles, and the other two oblique, thus in both instances preserving the joint-blocks at right-angles.

When block roads are laid with the strong sixteen-

feet rails now in use having four-feet bearings, we prefer the whole set at right-angles, the spaces afforded between them being sufficient for all practical purposes. But if diagonal blocks are introduced in these roads, we would recommend their being fixed as described for the twelve-foot rails.

In laying sleeper road the greatest care ought to be taken to have the templet for chairing the sleepers adjusted to the proper bevil, so that the chairs may have a true seat and equal bearing when close spiked thereto. The road should be laid as solidly as possible, and the sleepers securely beat up, and the ballast consolidated, previous to boxing up or finishing off the ballasting. By taking due pains and laying the road properly in the first instance, considerable labour and expense is avoided when it comes to be run upon. Larch sleepers are most commonly used. Their size is usually nine feet long, ten by five inches, or nine feet long and eight and a half by six inches at the smaller end. Spikes, six inches in length and three-quarters of an inch in diameter.

Sleeper roads with the strong rails now in use are mostly laid with four-feet bearings; but, on some descending lines, as an additional security, four middle sleepers are used to each length of sixteen-feet rails, the distances, of course, being furthest asunder in the middle of the rails.

In laying permanent road the greatest attention must be observed about closers, short ones being altogether inadmissible. They are at all times

dangerous on account of their aptness to work loose. By carefully measuring the distance to be closed in sufficient time, and selecting rails of proper lengths, short closers are easily avoided: rails being of various lengths both for this purpose and also for laying round curves. Care must also be taken to use expansion guages regularly at the joints, to allow the rails space to expand during hot weather.

CURVED ROADS.—These kind of roads must be very carefully laid, bearing in mind to keep using shorter rails occasionally for the inside, to prevent their overrunning the outside rails, and to preserve their joints opposite to each other. The outer rail in each line being also a little elevated above the other, in order to counteract by gravitation the tendency of carriages to proceed in a straight direction.

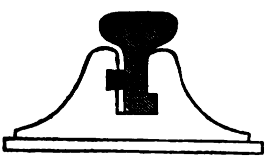
In some places where the degree of curvature is very great, stronger rails are used of a segmental form, and very judiciously, additional lateral strength being requisite at such places.

LEVEL CROSSINGS.—When a railway crosses a public road on a level it ought to be firmly paved, uniform on the top, and kept a little above the upper surface of the rails, to prevent carriages sustaining any shock whilst crossing over the line. The crossing should also be provided with proper check-rails, securely fixed to the sleepers to afford the flanges of railway carriage wheels a clear space to pass it without interruption.

An improved set of gates (four in number) has recently been adopted for those crossings, constructed

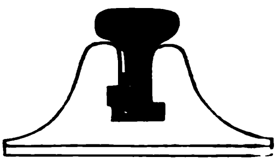
as follows:—Four upright cells of masonry, three feet diameter inside, are sunk beneath the line four feet in depth above their foundation. Into these cells four upright cast-iron moveable shafts are inserted, resting upon a pivot at the bottom, working in a plate, countersunk, and bolted to the masonry. The shafts are supported at the top of the cells by a cast-iron circular plate firmly bolted to the masonry, having two moveable screws attached thereto to preserve them perpendicularly: the shafts constituting the hanging-posts of the gates. Two feet from the bottom of the cells a connecting-wheel is attached to each shaft, and at the same level these wheels are connected together underneath the line by chains; thus by pushing one gate open it opens the other three, and closes them in the same manner. When the gates are open for the road they meet at the centre of the railway, and form a good fence on both sides of it for the crossing, and when shut effectually prevent any thing straying upon the line.

When the Liverpool and Manchester Railway was first laid the rails were fifteen feet in length, and weighed thirty-five lbs. per lineal yard. They were supported every three feet upon stone blocks, but upon the embankments transverse sleepers were used. The section annexed exhibits the mode of joining the rails to the chairs, the lightly shaded part representing



the rails. In passing the bars through the rollers a lateral projection is rolled upon one side of the rail, parallel with its upper surface; and on one side of the cheek of the chairs a longitudinal cavity is cast equal in size with the projection (see section). A little higher, on the opposite side, another similar hollow is cast for the purpose of receiving an iron key; and when the rail is laid into the chair, by driving the key, it presses against the side of the rail, which forces the projecting part of the latter into the opposite hollow, and thus secures each rail from rising up.

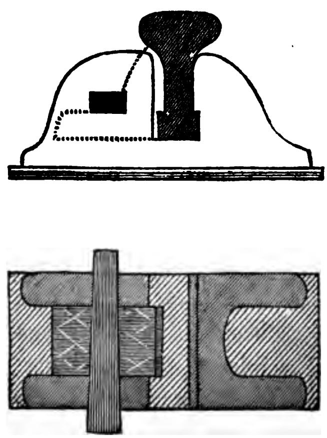
The above method of Mr. Stephenson's is somewhat different from that of Mr. Losh, which is as follows: — A projection is rolled on both sides of the rails, as drawn in the section; that on the right side entering a groove similar to the preceding. On the other cheek of the chair a longitudinal groove is cast, to receive a key, but, as shown in the figure, it is a double one, acting at the same time upon the upper part of the projection on the rail, to force it down



upon the chair, and against the side of the rail, both to steady it and to force the projection on the opposite side of the rail into the space referred to.

The late Mr. Steel, of Newcastle-on-Tyne, we believe was the first who introduced the parallel malleable-iron edge-rail, in the year 1829, when form-

ing the Clarence Railway, in the county of Durham; that is to say, the first excepting the introduction of the original flat and square bars. His rails had a kind of circular roll at the bottom one and a quarter inches in diameter. On one cheek of the chair a space was formed corresponding with this circular roll, the other being straight. The wedges used were straight on that side which was placed against the cheek of the chair, the other side having a circular cavity along the bottom similar to the hollow in the chair. One iron wedge was used to each chair, which filled the whole space between the latter and the rail; and, by driving the wedge, it pressed against the side of the rail, and forced the circular roll into the place for receiving it. The rails were four inches deep, and weighed thirty-two lbs. per lineal yard.



Another kind of chairs and different mode of keying, was also introduced upon the above railway. The lower drawing represents a horizontal section of the chair at the level of the under side of the rails. One cheek of the

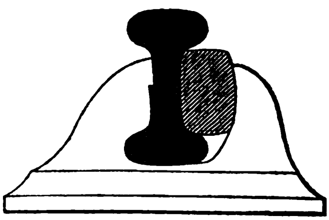
chair corresponds with the form of the rail, the other being open except for the thickness of its sides (one inch). An iron wedge of the form of an L, as marked by the dotted lines in the upper drawing, was placed between the sides of the chair, its base occupying the whole breadth thereof, and its front similar to the opposite cheek of the chair. By pushing the wedge forward it came in contact with the rail, and thus formed the other cheek. A hole was cast in each side of the chair (shaded dark in the upper drawing) through which an iron key was inserted. By driving the key it pressed against the back of the perpendicular part of the wedge, and against the upper surface of its base, and forced the projection on the rail into the space prepared for it at the bottom of the chair.

Various have been the modes resorted to for fastening the rails to the chairs. They were originally fastened by iron pins being inserted through the chair and rail. These were abandoned on account of their soon becoming loose and the difficulty of again securing them permanently. Recourse has since been had to different kinds of keys, pins, clasps, &c., but being composed of iron it was found impossible to prevent them working loose, or to cause their remaining in place, as by driving iron against iron there was nothing to yield, and if too tight driven the chairs became broken.

Subsequently a very great improvement took place by the introduction of wooden keys. These keys are made of good sound well-seasoned oak and

dried in kilns. The timber is forced through a mandrel of less size than the keys and thus becomes compressed. The outer cheek of the chairs is a little rounded horizontally; consequently, when the keys are driven therein, they are pressed most in their centre, and being to a certain extent elastic, are held secure themselves, and also prevent the rails from rising up or drawing in the direction which the trains run. Wooden keys also tend much to prevent that disagreeable jarring noise always experienced less or more where iron is used.

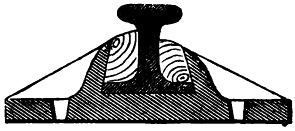
The preceding kinds of rails are now superseded by what is termed the H rail, both top and bottom being alike, as represented in the accompanying section. These rails possess many advantages, and are decidedly the best edge-rails hitherto introduced. They



may be reversed immediately if the least defect be observed on their upper surface. Or, when partly worn or injured at the top by reversing them they become very useful for secondary purposes, such as sidings, &c. The section referred to represents this kind of rail, chair, and key, as used on the Lancaster and Carlisle Railway. The rails are five inches in depth, and weigh seventy-five pounds per lineal yard. Base of joint-chairs, ten by five

inches. Middle chairs, ten by four and three-quarter inches.

On the Hull and Selby line flat bottomed rails are used. They are fastened in the chairs with *two* wooden keys, as shown in the margin; the chairs being widest at the bottom and narrowed upwards, which prevents the rails from rising up. The chairs are attached to cross sleepers, and the rails laid for the narrow guage.



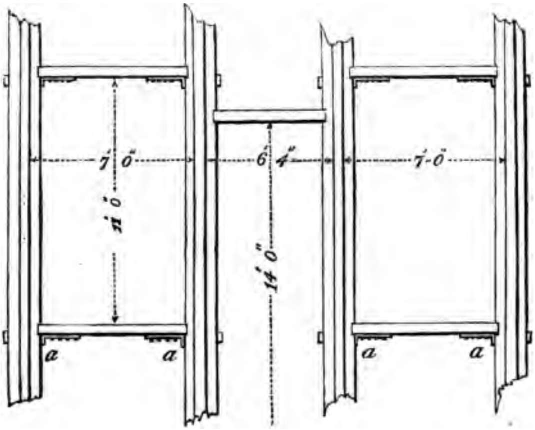
CONTINUOUS BEARINGS.—Another system of permanent roads consists of laying timber in continuous lines immediately underneath the rails, termed the longitudinal timbers, a system first introduced into this country by the engineer of the Great Western Railway.

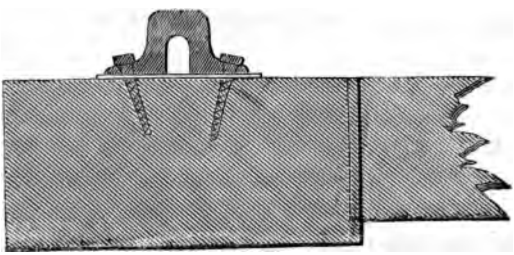
These timbers on the Great Western are fifteen inches in breadth, seven and a half inches in depth on the outside, and seven inches on the inside (see section), which gives the base of the *rails* the proper bevil. They are connected together, as described on the plan, by pieces of timber, six inches square, inserted into the longitudinal timbers marked by a dotted line on the section, and secured by iron knee-straps, &c. as exhibited on the plan at *a a a a*.

Upon the middle of the longitudinal timbers a piece of patent felt * is laid, its breadth corresponding

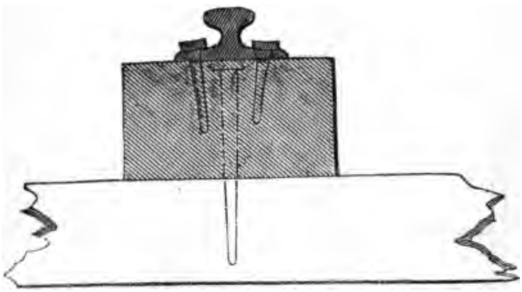
* Another kind of material is now preferred for this purpose, termed Mackintosh's Patent Vulcanized Indian Rubber.

with the base of the rails, which preserves them a true seat, and also a certain degree of elasticity between the rails and the timbers. The rails are hollow, arched underneath, and attached to the longitudinal timbers, by screws, as represented below.



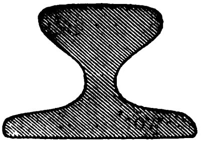


The Croyden Railway is also laid upon longitudinal timbers. They are four feet two inches asunder, being for the narrow guage, and nine inches in breadth by five inches deep, spiked to cross timbers laid underneath, three feet apart, centre and centre. The cross timbers are nine feet long, nine inches in breadth, by four and a half inches in depth. Solid rails are used, screwed to the longitudinal timbers, as exhibited in the section underneath.



The longitudinal timbers on the Newcastle-on-Tyne and North Shields Railway are twelve inches in breadth by six inches deep. These are connected together every eight feet by a piece of timber containing eighteen sectional inches, dove-tailed into the longitudinal timbers level with their upper surface. And upon the embankments near Newcastle, cross sleepers, twelve inches in breadth by six inches deep, are placed five feet apart underneath the longitudinal timbers.

The rails used are four and one-eighth inches in breadth at the base, two and a quarter inches on their upper surface, three quarters of an inch where narrowest, and two and three quarter inches in height (see section). They are from twelve to fifteen feet in length, and weigh fifty-three pounds per lineal yard. The rails are attached to the longitudinal timbers by screws, one side being fastened down alternately every twenty inches, except at each end where two screws are used. A piece of felt four inches in breadth is also placed under the rails.



MAINTENANCE.—In the maintenance of permanent roads the greatest attention and care of every person employed on the line is absolutely necessary, both with regard to the line itself and also the various works connected therewith.

Great attention must be paid to examine and keep in good repair the several bridges, culverts, fences, water-courses, drains, &c., especially for a few years after opening a line, as many of these works are apt to be filled up and injured. And on lines recently finished it is a good rule to observe that each foreman platelayer shall *walk over* and carefully examine the length under his charge early every morning, and also before leaving off in the evening; and that each foreman shall be responsible for the men employed with him.

In repairing permanent roads, platelayers ought

to be very careful not to pack the middle sleepers or blocks tighter than those at the joints, as it is very apt to cause the rails to become crooked. And so soon as either block or sleeper is out of place it should be repaired immediately, in order to preserve the rails as uniform and smooth as possible.

In opening out a line to be repaired, long lengths must be avoided, and it should be an invariable custom to *keep the rails clear*, both on the top and also for the flange of the wheels, to allow the trains to pass without obstruction. It ought also to be an invariable rule to keep the road clear of materials and work-tools, the latter being always removed when not in actual use; and no lengths left until they are either completed or made perfectly safe: completing them, however, is preferable.

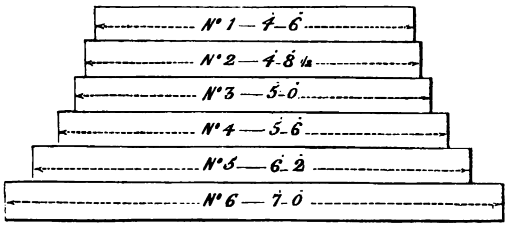
As embankments subside the road must necessarily be raised to the original level; therefore, additional ballast will be required from time to time, as it is impossible either to preserve a road with a smooth top or in line, unless the proper height of ballast is maintained; neither can sleepers be protected from the weather except they are sufficiently embedded. And on lines opened to the public no road should be raised more than two inches each lift.

The ballasting ought to be neatly finished off as each length is completed, and the surface drains renewed to cause the water to escape freely.* If the road under repair be a block road, common upright punners will be found very useful for re-consolidating

* See system of surface draining for permanent roads, page 135.

the ballast about the blocks after they are firmly packed underneath.

When any part of the permanent road is being repaired, and not safe to be run over at the usual speed, a signal-man must be in attendance at a sufficient distance from the place under repair, to meet and slow the trains; or, if the road be dangerous, to stop them until it is rectified. Signals, however, must only be entrusted to those who thoroughly understand them.



Where any rails are drawn a little (in the direction of the trains), the spaces ought to be equalised the first opportunity, taking especial care that the passage of regular trains is not interfered with, but on no account whatever must a single rail be unkeyed until the proper signals are attended to.*

The above diagram is a comparison of the different

* It would be a great improvement in joint-chairs were a narrow mark made across their upper surface on both sides to correspond with the joint of the rails. This would facilitate the laying the *joints* of the rails correctly in the centre of the chairs, and also show immediately if the rails became drawn as before described.

guages as laid on the several lines of railway. No. 1 represents the old 4 feet 6 inches guage. No. 2, the narrow guage, 4 feet 8½ inches; the narrow guage, however, differs on some lines, but only to the extent of half an inch in width, its guages being 4 feet 8½ inches, 4 feet 8¾ inches, and 4 feet 9 inches respectively. No. 3 represents the 5 feet guage of the Blackwall Railway. No. 4, the Scottish broad guage of the Arbroath and Forfar, and Dundee and Arbroath lines, 5 feet 6 inches. No. 5, the Ulster Railway, Irish guage, 6 feet 2 inches. And No. 6, the broad guage of 7 feet used on the Great Western and other railways.*

* The above guages are extracted from Mr. Weale's work on American and Belgian Railways.

CHAPTER IX.

EARTHWORK TABLES.

Table first, Batter of Slopes 1 to 1 — Table second, Batter of Slopes 1¼ to 1 — Table third, Batter of Slopes 1½ to 1 — Table fourth, Batter of Slopes 1¾ to 1 — Table fifth, Batter of Slopes 2 to 1.

THE following tables exhibit the number of cubic yards contained in a *Chain in Length*, the slopes of cuttings or embankments being worked as follows. Table first, batter of slopes 1 to 1.* Table second, 1¼ to 1. Table third, 1½ to 1. Table fourth, 1¾ to 1. And, Table fifth, 2 to 1.

Each column represents the number of cubic yards contained in a CHAIN IN LENGTH of cutting, arranged according to the depths given in the first columns, and the several breadths at the formation-level, namely, 18, 24, 27, 30, 33, and 36 feet respectively. The last columns show the number of cubic yards contained in a CENTRAL FOOT, agreeing with the first column depths, that is to say, 66 *feet in length multiplied by one foot in breadth and by the given depth in the first column.*

It was considered unnecessary to insert fractional parts in any of the tables except for the last columns.

* See Batter of Slopes explained, page 35.

In the other, where a fractional part was less than half a cubic yard, it has been omitted, and where it exceeded one-half, one cubic yard has been added to each integral quantity.

Should an excavation or embankment not correspond with any of the formation-breadths in the Tables, the cubic content may readily be found by adding to or deducting from any sum opposite the quantity in the last column (Central Foot) for every foot in breadth that it differs from the Table breadth; or in the same proportion for parts of feet. Thus one-half of the Central Foot must be taken for *six* inches, one-fourth of it for *three*, and so on.

Ex. 1. To find the cubic content of a *Chain in Length* of cutting, 39 feet 9 inches deep, batter of slopes 1 to 1, and breadth at the formation-level 31 feet?

	Cubic yds.
In the first Table, page 161, 30 feet in breadth contains . .	6777
And one Central Foot in breadth contains 97·17 cubic yards, which *add*	97·17
	6874·17 cub. yds.

Ex. 2. To find the cubic content of a *Chain in Length* of cutting, 39 feet 9 inches deep, batter of slopes 1 to 1, and breadth at the formation-level 29 feet?

	Cubic yds.
In the first Table, page 161, 30 feet in breadth contains . .	6777
And one Central Foot in breadth contains 97·17 cubic yards, which *deduct*	97·17
	6679·83 cub. yds.

Ex. 3. To find the cubic content of a *Chain in Length* of cutting, 41 feet 6 inches deep, batter of slopes 1 to 1, and breadth at the formation-level 31½ feet?

	Cubic yds.
In the same Table, page 161, 30 feet in breadth contains . .	7253
And one Central Foot in breadth contains 101·44 cubic yards = 152·16 cubic yards for 1½ feet, which *add*	152·16
	7405·16 cub. yds.

TABLE I.

Batter of Slopes 1 to 1.

Depths of Cutting. Ft.	in.	18 feet. cub. yds.	24 feet. cub. yds.	27 feet. cub. yds.	30 feet. cub. yds.	33 feet. cub. yds.	36 feet. cub. yds.	One Central Foot in breadth cub. yards.
1	0	47	61	68	76	83	90	2·44
1	3	59	77	86	96	105	114	3·06
1	6	72	94	105	116	127	138	3·67
1	9	84	110	123	136	149	162	4·28
2	0	98	127	142	156	171	186	4·89
2	3	111	144	161	177	194	210	5·50
2	6	125	162	180	199	217	235	6·11
2	9	140	180	200	220	240	260	6·72
3	0	154	198	220	242	264	286	7·33
3	3	169	217	240	264	288	312	7·94
3	6	184	235	261	287	312	338	8·55
3	9	199	254	282	309	337	364	9·17
4	0	215	274	303	332	362	391	9·78
4	3	231	293	325	356	387	418	10·39
4	6	248	314	347	380	413	446	11·
4	9	264	334	369	403	438	473	11·61
5	0	281	354	391	428	464	501	12·22
5	3	298	375	414	452	491	529	12·83
5	6	316	397	437	477	518	558	13·44
5	9	334	418	460	503	545	587	14·06
6	0	352	440	484	528	572	616	14·67
6	3	370	462	508	554	600	646	15·28
6	6	389	485	532	580	628	675	15·89
6	9	408	507	557	606	656	705	16·50

Batter of Slopes 1 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
7	0	428	530	582	633	684	736	17·11
7	3	448	554	607	660	713	766	17·72
7	6	468	578	633	688	743	798	18·33
7	9	488	602	658	715	772	829	18·94
8	0	509	626	684	743	802	860	19·55
8	3	529	650	711	771	832	892	20·17
8	6	551	675	738	800	862	925	20·78
8	9	572	700	765	829	893	957	21·39
9	0	594	726	792	858	924	990	22·
9	3	616	752	820	887	955	1023	22·61
9	6	639	778	848	917	987	1057	23·22
9	9	661	804	876	947	1019	1090	23·83
10	0	684	831	904	978	1051	1124	24·44
10	3	708	858	933	1009	1084	1159	25·06
10	6	731	886	963	1040	1117	1194	25·67
10	9	755	913	992	1071	1150	1229	26·28
11	0	780	941	1022	1102	1183	1264	26·89
11	3	804	969	1052	1134	1217	1299	27·50
11	6	829	998	1082	1167	1251	1335	28·11
11	9	855	1027	1113	1199	1285	1371	28·72
12	0	880	1056	1144	1232	1320	1408	29·33
12	3	906	1086	1175	1265	1355	1445	29·94
12	6	932	1115	1207	1299	1390	1482	30·55
12	9	958	1145	1239	1332	1426	1519	31·17
13	0	985	1176	1271	1366	1462	1557	31·78
13	3	1012	1206	1304	1401	1498	1595	32·39
13	6	1040	1238	1337	1436	1535	1634	33·
13	9	1067	1269	1370	1470	1571	1672	33·61

Batter of Slopes 1 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
14	0	1096	1300	1403	1506	1608	1711	34·22
14	3	1123	1332	1437	1541	1646	1750	34·83
14	6	1152	1365	1471	1577	1684	1790	35·44
14	9	1181	1397	1505	1614	1722	1830	36·06
15	0	1210	1430	1540	1650	1760	1870	36·67
15	3	1239	1463	1575	1687	1799	1911	37·28
15	6	1269	1497	1610	1724	1838	1951	37·89
15	9	1299	1530	1646	1761	1877	1992	38·50
16	0	1330	1564	1682	1799	1916	2034	39·11
16	3	1361	1599	1718	1837	1956	2075	39·72
16	6	1392	1634	1755	1876	1997	2118	40·33
16	9	1423	1669	1791	1914	2037	2160	40·94
17	0	1455	1704	1828	1953	2078	2202	41·55
17	3	1486	1739	1866	1992	2119	2245	42·17
17	6	1519	1775	1904	2032	2160	2289	42·78
17	9	1551	1811	1942	2072	2202	2332	43·39
18	0	1584	1848	1980	2112	2244	2376	44·
18	3	1617	1885	2019	2152	2286	2420	44·61
18	6	1651	1922	2058	2193	2329	2465	45·22
18	9	1684	1959	2097	2234	2372	2509	45·83
19	0	1719	1997	2136	2276	2415	2554	46·44
19	3	1753	2035	2176	2318	2459	2600	47·06
19	6	1788	2074	2217	2360	2503	2646	47·67
19	9	1822	2112	2257	2402	2547	2692	48·28
20	0	1858	2151	2298	2444	2591	2738	48·89
20	3	1893	2190	2339	2487	2636	2784	49·50
20	6	1929	2230	2380	2531	2681	2831	50·11
20	9	1966	2270	2422	2574	2726	2878	50·72

Batter of Slopes 1 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
21	0	2002	2310	2464	2618	2772	2926	51·33
21	3	2039	2351	2506	2662	2818	2974	51·94
21	6	2076	2391	2549	2707	2864	3022	52·55
21	9	2113	2432	2592	2751	2911	3070	53·17
22	0	2151	2474	2635	2796	2958	3119	53·78
22	3	2189	2515	2679	2842	3005	3168	54·39
22	6	2228	2558	2723	2888	3053	3218	55·
22	9	2266	2600	2767	2933	3100	3267	55·61
23	0	2305	2642	2811	2980	3148	3317	56·22
23	3	2344	2685	2856	3026	3197	3367	56·83
23	6	2384	2729	2901	3073	3246	3418	57·44
23	9	2424	2772	2946	3121	3295	3469	58·06
24	0	2464	2816	2992	3168	3344	3520	58·67
24	3	2504	2860	3038	3216	3394	3572	59·28
24	6	2545	2905	3084	3264	3444	3623	59·89
24	9	2586	2949	3131	3312	3494	3675	60·50
25	0	2628	2994	3178	3361	3544	3728	61·11
25	3	2670	3040	3225	3410	3595	3780	61·72
25	6	2712	3086	3273	3460	3647	3834	62·33
25	9	2754	3132	3320	3509	3698	3887	62·94
26	0	2797	3178	3368	3559	3750	3940	63·55
26	3	2839	3224	3417	3609	3802	3994	64·17
26	6	2883	3271	3466	3660	3854	4049	64·78
26	9	2926	3318	3515	3711	3907	4103	65·39
27	0	2970	3366	3564	3762	3960	4158	66·
27	3	3014	3414	3614	3813	4013	4213	66·61
27	6	3059	3462	3664	3865	4067	4269	67 22
27	9	3103	3510	3714	3917	4121	4324	67·83

Batter of Slopes 1 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
28	0	3149	3559	3764	3970	4175	4380	68·44
28	3	3194	3608	3815	4023	4230	4437	69·06
28	6	3240	3658	3867	4076	4285	4494	69·67
28	9	3285	3707	3918	4129	4340	4551	70·28
29	0	3332	3757	3970	4182	4395	4608	70·89
29	3	3378	3807	4022	4236	4451	4665	71·50
29	6	3426	3858	4074	4291	4507	4723	72·11
29	9	3473	3909	4127	4345	4563	4781	72·72
30	0	3520	3960	4180	4400	4620	4840	73·33
30	3	3568	4013	4233	4455	4677	4899	73·94
30	6	3616	4063	4287	4511	4734	4958	74·55
30	9	3664	4115	4341	4566	4792	5017	75·17
31	0	3713	4168	4395	4622	4850	5077	75·78
31	3	3762	4220	4450	4679	4908	5137	76·39
31	6	3812	4274	4505	4736	4967	5198	77·
31	9	3861	4327	4560	4792	5025	5258	77·61
32	0	3911	4380	4615	4850	5084	5319	78·22
32	3	3961	4434	4671	4907	5144	5380	78·83
32	6	4012	4489	4727	4965	5204	5442	79·44
32	9	4063	4543	4783	5024	5264	5504	80·06
33	0	4114	4598	4840	5082	5324	5566	80·67
33	3	4165	4653	4897	5141	5385	5629	81·28
33	6	4217	4709	4954	5200	5446	5691	81·89
33	9	4269	4764	5012	5259	5507	5754	82·50
34	0	4322	4820	5070	5319	5568	5818	83·11
34	3	4375	4877	5128	5379	5630	5881	83·72
34	6	4428	4934	5187	5440	5693	5946	84·33
34	9	4481	4991	5245	5500	5755	6010	84·94

Batter of Slopes 1 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
35	0	4535	5048	5304	5561	5818	6074	85·55
35	3	4588	5105	5364	5622	5881	6139	86·17
35	6	4643	5163	5424	5684	5944	6205	86·78
35	9	4697	5221	5484	5746	6008	6270	87·39
36	0	4752	5280	5544	5808	6072	6336	88·
36	3	4807	5339	5605	5870	6136	6402	88·61
36	6	4863	5398	5666	5933	6201	6469	89·22
36	9	4918	5457	5727	5996	6266	6535	89·83
37	0	4975	5517	5788	6060	6331	6602	90·44
37	3	5031	5577	5850	6124	6397	6670	91·06
37	6	5088	5638	5913	6188	6463	6738	91·67
37	9	5144	5698	5975	6252	6529	6806	92·28
38	0	5202	5759	6038	6316	6595	6874	92·89
38	3	5259	5820	6101	6381	6662	6942	93·50
38	6	5318	5882	6164	6447	6729	7011	94·11
38	9	5376	5944	6228	6512	6796	7080	94·72
39	0	5434	6006	6292	6578	6864	7150	95·33
39	3	5493	6069	6356	6644	6932	7220	95·94
39	6	5552	6131	6421	6711	7000	7290	96·55
39	9	5611	6194	6486	6777	7069	7360	97·17
40	0	5671	6258	6551	6844	7138	7431	97·78
40	3	5731	6321	6617	6912	7207	7502	98·39
40	6	5791	6386	6683	6980	7277	7574	99·
40	9	5852	6450	6749	7047	7346	7645	99·61
41	0	5913	6515	6815	7116	7416	7717	100·22
41	3	5974	6579	6882	7184	7487	7789	100·83
41	6	6036	6645	6949	7253	7558	7862	101·44
41	9	6098	6710	7016	7323	7629	7935	102·06

Batter of Slopes 1 to 1.

Depths of Cutting.		Breadths at Formation-Level. 18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	One Central Foot in breadth
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
42	0	6160	6776	7084	7392	7700	8008	102·67
42	3	6222	6842	7152	7462	7772	8082	103·28
42	6	6285	6909	7220	7532	7844	8155	103·89
42	9	6348	6975	7289	7602	7916	8229	104·50
43	0	6412	7042	7358	7673	7988	8304	105·11
43	3	6475	7109	7427	7744	8061	8378	105·72
43	6	6540	7178	7497	7816	8135	8454	106·33
43	9	6604	7246	7566	7887	8208	8529	106·94
44	0	6669	7314	7636	7959	8282	8604	107·55
44	3	6733	7382	7707	8031	8356	8680	108·17
44	6	6799	7451	7778	8104	8430	8757	108·78
44	9	6864	7520	7849	8177	8505	8833	109·39
45	0	6930	7590	7920	8250	8580	8910	110·
45	3	6996	7660	7992	8323	8655	8987	110·61
45	6	7063	7730	8064	8397	8731	9065	111·22
45	9	7129	7800	8136	8471	8807	9142	111·83
46	0	7196	7871	8208	8546	8883	9220	112·44
46	3	7264	7942	8281	8621	8960	9299	113·06
46	6	7332	8014	8355	8696	9037	9378	113·67
46	9	7399	8085	8428	8771	9114	9457	114·28
47	0	7468	8157	8502	8846	9191	9536	114·89
47	3	7536	8229	8576	8922	9269	9615	115·50
47	6	7606	8302	8650	8999	9347	9695	116·11
47	9	7675	8375	8725	9075	9425	9775	116·72
48	0	7744	8448	8800	9152	9504	9856	117·33
48	3	7814	8522	8875	9229	9583	9937	117·94
48	6	7884	8595	8951	9307	9662	10018	118·55
48	9	7954	8669	9027	9384	9742	10099	119·17

Batter of Slopes 1 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
49	0	8025	8744	9103	9462	9822	10181	119·78
49	3	8096	8818	9180	9541	9902	10263	120·29
49	6	8168	8894	9257	9620	9983	10346	121·
49	9	8239	8969	9334	9698	10063	10428	121·61
50	0	8311	9045	9411	9778	10144	10511	122·22
50	3	8383	9120	9489	9857	10226	10594	122·83
50	6	8456	9197	9567	9937	10308	10678	123·44
50	9	8529	9273	9645	10018	10390	10762	124·06
51	0	8602	9350	9724	10098	10472	10846	124·67
51	3	8675	9427	9803	10179	10555	10931	125·28
51	6	8749	9505	9882	10260	10638	11015	125·89
51	9	8823	9582	9962	10341	10721	11100	126·50
52	0	8898	9660	10042	10423	10804	11186	127·11
52	3	8973	9739	10122	10505	10888	11271	127·72
52	6	9048	9818	10203	10588	10973	11358	128·33
52	9	9123	9897	10283	10670	11057	11444	128·94
53	0	9199	9976	10364	10753	11142	11530	129·55
53	3	9274	10055	10446	10836	11227	11617	130·17
53	6	9351	10135	10528	10920	11312	11705	130·78
53	9	9427	10215	10610	11004	11398	11792	131·39
54	0	9504	10296	10692	11088	11484	11880	132·
54	3	9581	10377	10775	11172	11570	11968	132·61
54	6	9659	10458	10858	11257	11657	12057	133·22
54	9	9736	10539	10941	11342	11744	12145	133·83
55	0	9814	10621	11024	11428	11831	12234	134·44
55	3	9893	10703	11108	11514	11919	12324	135·06
55	6	9972	10786	11193	11600	12007	12414	135·67
55	9	10050	10868	11277	11686	12095	12504	136·28

Batter of Slopes 1 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
56	0	10130	10951	11362	11772	12183	12594	136·89
56	3	10209	11034	11447	11859	12272	12684	137·50
56	6	10289	11118	11532	11947	12361	12775	138·11
56	9	10370	11202	11618	12034	12450	12866	138·72
57	0	10450	11286	11704	12122	12540	12958	139·33
57	3	10531	11371	11790	12210	12630	13050	139·94
57	6	10612	11455	11877	12299	12720	13142	140·55
57	9	10693	11540	11964	12387	12811	13234	141·17
58	0	10775	11626	12051	12476	12902	13327	141·78
58	3	10857	11711	12139	12566	12993	13420	142·39
58	6	10939	11798	12227	12656	13085	13514	143·
58	9	11022	11884	12315	12745	13176	13607	143·61
59	0	11105	11971	12403	12836	13268	13701	144·22
59	3	11188	12057	12492	12926	13361	13795	144·83
59	6	11272	12145	12581	13017	13454	13890	145·44
59	9	11356	12232	12670	13109	13547	13985	146·06
60	0	11440	12320	12760	13200	13640	14080	146·67
60	3	11524	12408	12850	13292	13734	14176	147·28
60	6	11609	12497	12940	13384	13828	14271	147·89
60	9	11694	12585	13031	13476	13922	14367	148·50
61	0	11780	12674	13122	13569	14016	14464	149·11
61	3	11866	12764	13213	13662	14111	14560	149·72
61	6	11952	12854	13305	13756	14207	14658	150·33
61	9	12038	12944	13396	13849	14302	14755	150·94
62	0	12125	13034	13488	13943	14398	14852	151·55
62	3	12211	13124	13581	14037	14494	14950	152·17
62	6	12299	13215	13674	14132	14590	15049	152·78
62	9	12386	13306	13767	14227	14687	15147	153·39

Batter of Slopes 1 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
63	0	12474	13398	13860	14322	14784	15246	154·
63	3	12562	13490	13954	14417	14881	15345	154·61
63	6	12651	13582	14048	14513	14979	15445	155·22
63	9	12739	13674	14142	14609	15077	15544	155·83
64	0	12829	13767	14236	14706	15175	15644	156·44
64	3	12918	13860	14331	14803	15274	15745	157·06
64	6	13008	13954	14427	14900	15373	15846	157·67
64	9	13097	14047	14522	14997	15472	15947	158·28
65	0	13188	14141	14618	15094	15571	16048	158·89
65	3	13278	14235	14714	15192	15671	16149	159·50
65	6	13369	14330	14810	15291	15771	16251	160·11
65	9	13461	14425	14907	15389	15871	16353	160·72
66	0	13552	14520	15004	15488	15972	16456	161·33
66	3	13644	14616	15101	15587	16073	16559	161·94
66	6	13736	14711	15199	15687	16174	16662	162·55
66	9	13828	14807	15297	15786	16276	16765	163·17
67	0	13921	14904	15395	15886	16378	16869	163·78
67	3	14014	15000	15494	15987	16480	16973	164·39
67	6	14108	15098	15593	16088	16583	17078	165·
67	9	14201	15195	15692	16188	16685	17182	165·61
68	0	14295	15293	15791	16290	16788	17287	166·22
68	3	14389	15390	15891	16391	16892	17392	166·83
68	6	14484	15489	15991	16493	16996	17498	167·44
68	9	14579	15587	16091	16596	17100	17604	168·06
69	0	14674	15686	16192	16698	17204	17710	168·67
69	3	14769	15785	16293	16801	17309	17817	169·28
69	6	14865	15885	16394	16904	17414	17923	169·89
69	9	14961	15984	16496	17007	17519	18030	170·50
70	0	15058	16084	16598	17111	17624	18138	171·11

TABLE II.

Batter of Slopes 1½ to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
1	0	47	62	69	76	84	91	2·44
1	3	60	78	87	96	106	115	3·06
1	6	73	95	106	117	128	139	3·67
1	9	86	112	125	138	151	163	4·28
2	0	100	130	144	159	174	188	4·89
2	3	114	147	164	180	197	213	5·50
2	6	129	166	184	202	221	239	6·11
2	9	144	184	205	225	245	265	6·72
3	0	160	204	226	248	270	292	7·33
3	3	175	223	247	271	294	318	7·94
3	6	192	243	268	294	320	345	8·55
3	9	208	263	290	318	345	373	9·17
4	0	225	284	313	342	372	401	9·78
4	3	242	305	336	367	398	429	10·39
4	6	260	326	359	392	425	458	11·
4	9	278	348	382	417	452	487	11·61
5	0	296	370	406	443	480	516	12·22
5	3	315	392	431	469	508	546	12·83
5	6	335	415	455	496	536	576	13·44
5	9	354	438	481	523	565	607	14·06
6	0	374	462	506	550	594	638	14·67
6	3	394	486	532	578	624	669	15·28
6	6	415	510	558	606	653	701	15·89
6	9	436	535	585	634	684	733	16·50

Batter of Slopes, 1¼ to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds	cub. yards.
7	0	458	560	612	663	714	766	17·11
7	3	480	586	639	692	745	799	17·72
7	6	502	612	667	722	777	832	18·33
7	9	525	638	695	752	809	865	18·94
8	0	548	665	724	782	841	900	19·55
8	3	571	692	752	813	873	934	20·17
8	6	595	719	782	844	906	969	20·78
8	9	619	747	811	876	940	1004	21·39
9	0	644	776	842	908	974	1040	22·
9	3	668	804	872	940	1008	1075	22·61
9	6	694	833	903	972	1042	1112	23·22
9	9	720	862	934	1005	1077	1148	23·83
10	0	746	892	966	1039	1112	1186	24·44
10	3	772	922	998	1073	1148	1223	25·06
10	6	799	953	1030	1107	1184	1261	25·67
10	9	826	984	1063	1141	1220	1299	26·28
11	0	854	1015	1096	1176	1257	1338	26·89
11	3	882	1047	1129	1212	1294	1377	27·50
11	6	910	1079	1163	1247	1332	1416	28·11
11	9	939	1111	1197	1284	1370	1456	28·72
12	0	968	1144	1232	1320	1408	1496	29·33
12	3	998	1177	1267	1357	1447	1536	29·94
12	6	1028	1211	1302	1394	1486	1577	30·55
12	9	1058	1245	1338	1432	1525	1619	31·17
13	0	1088	1279	1374	1470	1565	1660	31·78
13	3	1119	1314	1411	1508	1605	1702	32·39
13	6	1151	1349	1448	1547	1646	1745	33·
13	9	1183	1384	1485	1586	1687	1788	33·61

BATTER OF SLOPES $1\frac{1}{4}$ TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	In.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
14	0	1215	1420	1523	1626	1728	1831	34·22
14	3	1248	1457	1561	1666	1770	1874	34·83
14	6	1281	1493	1599	1706	1812	1918	35·44
14	9	1314	1530	1638	1746	1855	1963	36·06
15	0	1348	1568	1678	1788	1898	2008	36·67
15	3	1382	1605	1717	1829	1941	2053	37·28
15	6	1416	1643	1757	1871	1984	2098	37·89
15	9	1451	1682	1797	1913	2028	2144	38·50
16	0	1486	1721	1838	1956	2073	2190	39·11
16	3	1522	1760	1879	1999	2118	2237	39·72
16	6	1558	1800	1921	2042	2163	2284	40·33
16	9	1594	1840	1963	2086	2208	2331	40·94
17	0	1631	1880	2005	2130	2254	2379	41·55
17	3	1668	1921	2048	2174	2301	2427	42·17
17	6	1706	1962	2091	2219	2347	2476	42·78
17	9	1744	2004	2134	2264	2395	2525	43·39
18	0	1782	2046	2178	2310	2442	2574	44·
18	3	1821	2088	2222	2356	2490	2624	44·61
18	6	1860	2131	2267	2402	2538	2674	45·22
18	9	1899	2174	2312	2449	2587	2724	45·83
19	0	1939	2218	2357	2496	2636	2775	46·44
19	3	1979	2262	2403	2544	2685	2826	47·06
19	6	2020	2306	2449	2592	2735	2878	47·67
19	9	2061	2351	2495	2640	2785	2930	48·28
20	0	2102	2396	2542	2689	2836	2982	48·89
20	3	2144	2441	2589	2738	2886	3035	49·50
20	6	2186	2487	2637	2787	2938	3088	50·11
20	9	2229	2533	2685	2837	2989	3142	50·72

Batter of Slopes $1\frac{1}{4}$ to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
21	0	2272	2580	2734	2888	3042	3196	51·33
21	3	2315	2626	2782	2938	3094	3250	51·94
21	6	2359	2674	2831	2989	3147	3304	52·55
21	9	2402	2722	2881	3041	3200	3360	53·17
22	0	2447	2770	2931	3092	3254	3415	53·78
22	3	2492	2818	2981	3144	3308	3471	54·39
22	6	2537	2867	3032	3197	3362	3527	55·
22	9	2582	2916	3083	3250	3417	3583	55·61
23	0	2628	2966	3134	3303	3472	3640	56·22
23	3	2675	3016	3186	3357	3527	3698	56·83
23	6	2722	3066	3238	3411	3583	3755	57·44
23	9	2769	3117	3291	3465	3639	3814	58·06
24	0	2816	3168	3344	3520	3696	3872	58·67
24	3	2864	3220	3397	3575	3753	3931	59·28
24	6	2912	3271	3451	3631	3810	3990	59·89
24	9	2961	3324	3505	3687	3868	4050	60·50
25	0	3010	3376	3560	3743	3926	4110	61·11
25	3	3059	3429	3615	3800	3985	4170	61·72
25	6	3109	3483	3670	3857	4044	4231	62·33
25	9	3159	3537	3726	3914	4103	4292	62·94
26	0	3210	3591	3782	3972	4163	4354	63·55
26	3	3260	3646	3838	4031	4223	4416	64·17
26	6	3312	3700	3895	4089	4283	4478	64·78
26	9	3363	3756	3952	4148	4344	4540	65·39
27	0	3416	3812	4010	4208	4406	4604	66·
27	3	3468	3868	4067	4267	4467	4667	66·61
27	6	3521	3924	4126	4327	4529	4731	67·22
27	9	3574	3981	4184	4388	4592	4795	67·83

Batter of Slopes 1¼ to 1.

Depths of Cutting. Ft.	in.	Breadths at Formation-Level. 18 feet. cub. yds.	24 feet. cub. yds.	27 feet. cub. yds.	30 feet. cub. yds.	33 feet. cub. yds.	36 feet. cub. yds.	One Central Foot in breadth cub. yards.
28	0	3628	4038	4244	4449	4654	4860	68·44
28	3	3682	4096	4303	4510	4717	4925	69·06
28	6	3736	4154	4363	4572	4781	4990	69·67
28	9	3791	4212	4423	4634	4845	5056	70·28
29	0	3846	4271	4484	4696	4909	5122	70·89
29	3	3901	4330	4545	4759	4974	5188	71·50
29	6	3957	4390	4606	4822	5039	5255	72·11
29	9	4013	4450	4668	4886	5104	5322	72·72
30	0	4070	4510	4730	4950	5170	5390	73·33
30	3	4127	4571	4793	5014	5236	5458	73·94
30	6	4185	4632	4855	5079	5303	5526	74·55
30	9	4242	4693	4919	5144	5370	5595	75·17
31	0	4300	4755	4982	5210	5437	5664	75·78
31	3	4359	4817	5046	5276	5505	5734	76·39
31	6	4418	4880	5111	5342	5573	5804	77·
31	9	4477	4943	5176	5409	5641	5874	77·61
32	0	4537	5006	5241	5476	5710	5945	78·22
32	3	4597	5070	5306	5543	5779	6016	78·83
32	6	4658	5134	5372	5611	5849	6087	79·44
32	9	4718	5199	5439	5679	5919	6159	80·06
33	0	4780	5264	5506	5748	5990	6232	80·67
33	3	4841	5329	5573	5816	6060	6304	81·28
33	6	4903	5394	5640	5886	6131	6377	81·89
33	9	4965	5460	5708	5955	6203	6450	82·50
34	0	5028	5527	5776	6026	6275	6524	83·11
34	3	5091	5594	5845	6096	6347	6598	83·72
34	6	5155	5661	5914	6167	6420	6673	84·33
34	9	5219	5728	5983	6238	6493	6748	84·94

BATTER OF SLOPES 1¼ TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet	36 feet.	in breadth.
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
35	0	5283	5796	6053	6310	6566	6823	85·55
35	3	5348	5865	6123	6382	6640	6899	86·17
35	6	5413	5933	6194	6454	6714	6975	86·78
35	9	5478	6003	6265	6527	6789	7051	87·39
36	0	5544	6072	6336	6600	6864	7128	88·
36	3	5610	6142	6408	6674	6939	7205	88·61
36	6	5677	6212	6480	6747	7015	7283	89·22
36	9	5744	6283	6552	6822	7091	7361	89·83
37	0	5811	6354	6625	6896	7168	7439	90·44
37	3	5879	6425	6698	6971	7245	7518	91·06
37	6	5947	6497	6772	7047	7322	7597	91·67
37	9	6015	6569	6846	7123	7400	7676	92·28
38	0	6084	6642	6920	7199	7478	7756	92·89
38	3	6153	6714	6995	7275	7556	7836	93·50
38	6	6223	6788	7070	7352	7635	7917	94·11
38	9	6293	6861	7146	7430	7714	7998	94·72
39	0	6364	6936	7222	7508	7794	8080	95·33
39	3	6434	7010	7298	7586	7873	8161	95·94
39	6	6506	7085	7374	7664	7954	8243	96·55
39	9	6577	7160	7451	7743	8034	8326	97·17
40	0	6649	7236	7529	7822	8116	8409	97·78
40	3	6721	7312	7607	7902	8197	8492	98·39
40	6	6794	7388	7685	7982	8279	8576	99·
40	9	6867	7465	7763	8062	8361	8660	99·61
41	0	6940	7542	7842	8143	8444	8744	100·22
41	3	7014	7619	7922	8224	8527	8829	100·83
41	6	7089	7697	8001	8306	8610	8914	101·44
41	9	7163	7775	8082	8388	8694	9000	102·06

Batter of Slopes $1\frac{1}{4}$ to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
42	0	7238	7854	8162	8470	8778	9086	102·67
42	3	7313	7933	8243	8553	8863	9172	103·28
42	6	7389	8012	8324	8636	8947	9259	103·89
42	9	7465	8092	8406	8719	9033	9346	104·50
43	0	7542	8172	8488	8803	9118	9434	105·11
43	3	7619	8253	8570	8887	9204	9522	105·72
43	6	7696	8334	8653	8972	9291	9610	106·33
43	9	7774	8416	8736	9057	9378	9698	106·94
44	0	7852	8497	8820	9142	9465	9788	107·55
44	3	7930	8579	8903	9228	9552	9877	108·17
44	6	8009	8661	8988	9314	9640	9967	108·78
44	9	8088	8744	9072	9401	9729	10057	109·39
45	0	8168	8828	9158	9488	9818	10148	110·
45	3	8247	8911	9243	9575	9907	10238	110·61
45	6	8328	8995	9329	9662	9996	10330	111·22
45	9	8409	9079	9415	9750	10086	10421	111·83
46	0	8490	9164	9502	9839	10176	10514	112·44
46	3	8571	9249	9589	9928	10267	10606	113·06
46	6	8653	9335	9676	10017	10358	10699	113·67
46	9	8735	9421	9764	10106	10449	10792	114·28
47	0	8818	9507	9852	10196	10541	10886	114·89
47	3	8901	9594	9940	10287	10633	10980	115·50
47	6	8984	9681	10029	10377	10726	11074	116·11
47	9	9068	9768	10118	10469	10819	11169	116·72
48	0	9152	9856	10208	10560	10912	11264	117·33
48	3	9237	9944	10298	10652	11006	11359	117·94
48	6	9322	10033	10388	10744	11100	11455	118·55
48	9	9407	10122	10479	10837	11194	11552	119·17

BATTER OF SLOPES 1¼ TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
49	0	9492	10211	10570	10930	11289	11648	119·78
49	3	9578	10301	10662	11023	11384	11745	120·39
49	6	9665	10391	10754	11117	11480	11843	121·
49	9	9752	10481	10846	11211	11576	11941	121·61
50	0	9839	10572	10939	11306	11672	12039	122·22
50	3	9927	10663	11032	11400	11769	12137	122·83
50	6	10015	10755	11125	11496	11866	12236	123·44
50	9	10103	10847	11219	11591	11964	12336	124·06
51	0	10192	10940	11314	11688	12062	12436	124·67
51	3	10281	11032	11408	11784	12160	12536	125·28
51	6	10370	11126	11503	11881	12258	12636	125·89
51	9	10460	11219	11598	11978	12357	12737	126·50
52	0	10550	11313	11694	12076	12457	12838	127·11
52	3	10641	11407	11790	12174	12557	12940	127·72
52	6	10732	11502	11887	12272	12657	13042	128·33
52	9	10823	11597	11984	12371	12757	13144	128·94
53	0	10915	11692	12081	12470	12858	13247	129·55
53	3	11007	11788	12179	12569	12960	13350	130·17
53	6	11100	11884	12277	12669	13061	13454	130·78
53	9	11193	11981	12375	12769	13164	13558	131·39
54	0	11286	12078	12474	12870	13266	13662	132·
54	3	11380	12175	12573	12971	13369	13767	132·61
54	6	11474	12273	12673	13072	13472	13872	133·22
54	9	11568	12371	12773	13174	13576	13977	133·83
55	0	11663	12470	12873	13276	13680	14083	134·44
55	3	11758	12569	12974	13379	13784	14189	135·06
55	6	11854	12668	13075	13482	13889	14296	135·67
55	9	11950	12768	13176	13585	13994	14403	136·28

Batter of Slopes 1¼ to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	In.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
56	0	12046	12868	13278	13689	14100	14510	136·89
56	3	12143	12968	13380	13793	14205	14618	137·50
56	6	12240	13069	13483	13897	14312	14726	138·11
56	9	12338	13170	13586	14002	14418	14835	138·72
57	0	12436	13272	13690	14108	14526	14944	139·33
57	3	12534	13374	13793	14213	14633	15053	139·94
57	6	12633	13476	13897	14319	14741	15162	140·55
57	9	12731	13578	14002	14425	14849	15273	141·17
58	0	12831	13682	14107	14532	14958	15383	141·78
58	3	12931	13785	14212	14639	15067	15494	142·39
58	6	13031	13889	14318	14747	15176	15605	143·
58	9	13131	13993	14424	14855	15286	15716	143·61
59	0	13232	14098	14530	14963	15396	15828	144·22
59	3	13334	14203	14637	15072	15506	15941	144·83
59	6	13436	14308	14744	15181	15617	16053	145·44
59	9	13538	14414	14852	15290	15728	16167	146·06
60	0	13640	14520	14960	15400	15840	16280	146·67
60	3	13743	14627	15068	15510	15952	16394	147·28
60	6	13846	14734	15177	15621	16064	16508	147·89
60	9	13950	14841	15286	15732	16177	16623	148·50
61	0	14054	14948	15396	15843	16290	16738	149·11
61	3	14158	15056	15506	15955	16404	16853	149·72
61	6	14263	15165	15616	16067	16518	16969	150·33
61	9	14368	15274	15727	16179	16632	17085	150·94
62	0	14474	15383	15838	16292	16747	17202	151·55
62	3	14579	15492	15949	16405	16862	17319	152·17
62	6	14686	15602	16061	16519	16977	17436	152·78
62	9	14792	15713	16173	16633	17093	17553	153·39

Batter of Slopes $1\frac{1}{4}$ to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
63	0	14900	15824	16286	16748	17210	17672	154·
63	3	15007	15935	16398	16862	17326	17790	154·61
63	6	15115	16046	16512	16977	17443	17909	155·22
63	9	15223	16158	16625	17093	17560	18028	155·83
64	0	15332	16270	16740	17209	17678	18148	156·44
64	3	15441	16383	16854	17325	17796	18268	157·06
64	6	15550	16496	16969	17442	17915	18388	157·67
64	9	15660	16609	17084	17559	18034	18509	158·28
65	0	15770	16723	17200	17676	18153	18630	158·89
65	3	15880	16837	17316	17794	18273	18751	159·50
65	6	15991	16952	17432	17912	18393	18873	160·11
65	9	16102	17067	17549	18031	18513	18995	160·72
66	0	16214	17182	17666	18150	18634	19118	161·33
66	3	16326	17298	17784	18269	18755	19241	161·94
66	6	16439	17414	17901	18389	18877	19364	162·55
66	9	16551	17530	18020	18509	18999	19488	163·17
67	0	16664	17647	18138	18630	19121	19612	163·78
67	3	16778	17764	18257	18751	19244	19737	164·39
67	6	16892	17882	18377	18872	19367	19862	165·
67	9	17006	18000	18497	18994	19490	19987	165·61
68	0	17121	18118	18617	19116	19614	20113	166·22
68	3	17236	18237	18737	19238	19738	20239	166·83
68	6	17352	18356	18858	19361	19863	20365	167·44
68	9	17467	18476	18980	19484	19988	20492	168·06
69	0	17584	18596	19102	19608	20114	20620	168·67
69	3	17700	18716	19224	19731	20239	20747	169·28
69	6	17817	18837	19346	19856	20365	20875	169·89
69	9	17934	18957	19469	19980	20492	21003	170·50
70	0	18052	19079	19592	20106	20619	21132	171·11

TABLE III.

BATTER OF SLOPES $1\frac{1}{2}$ TO 1.

Depths of Cutting.		Breadths at Formation-Level. 18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	One Central Foot in breadth
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
1	0	48	62	70	77	84	92	2·44
1	3	61	79	88	97	107	116	3·06
1	6	74	96	107	118	129	140	3·67
1	9	88	114	127	140	152	165	4·28
2	0	103	132	147	161	176	191	4·89
2	3	118	151	167	184	200	217	5·50
2	6	133	170	188	206	225	243	6·11
2	9	149	189	209	229	250	270	6·72
3	0	165	209	231	253	275	297	7·33
3	3	182	229	253	277	301	325	7·94
3	6	199	250	276	302	327	353	8·55
3	9	217	272	299	327	354	382	9·17
4	0	235	293	323	352	381	411	9·78
4	3	253	316	347	378	409	440	10·39
4	6	272	338	371	404	437	470	11·
4	9	292	361	396	431	466	501	11·61
5	0	312	385	422	458	495	532	12·22
5	3	332	409	448	486	525	563	12·83
5	6	353	434	474	514	555	595	13·44
5	9	374	459	501	543	585	627	14·06
6	0	396	484	528	572	616	660	14·67
6	3	418	510	556	602	647	693	15·28
6	6	441	536	584	632	679	727	15·89
6	9	464	563	613	662	712	761	16·50

Batter of Slopes 1½ to 1.

Depths of Cutting.		Breadths at Formation-Level. 18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	One Central Foot in breadth
Ft.	in.	cub. yds.	cub. yds	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
7	0	488	590	642	693	744	796	17·11
7	3	512	618	671	724	778	831	17·72
7	6	536	646	701	756	811	866	18·33
7	9	561	675	732	789	845	902	18·94
8	0	587	704	763	821	880	939	19·55
8	3	613	734	794	855	915	976	20·17
8	6	639	764	826	888	951	1013	20·78
8	9	666	794	858	922	987	1051	21·39
9	0	693	825	891	957	1023	1089	22·
9	3	721	856	924	992	1060	1128	22·61
9	6	749	888	958	1028	1097	1167	23·22
9	9	778	921	992	1064	1135	1207	23·83
10	0	807	953	1027	1100	1173	1247	24·44
10	3	836	987	1062	1137	1212	1287	25·06
10	6	866	1020	1097	1174	1251	1328	25·67
10	9	897	1054	1133	1212	1291	1370	26·28
11	0	928	1089	1170	1250	1331	1412	26·89
11	3	959	1124	1207	1289	1372	1454	27·50
11	6	991	1160	1244	1328	1413	1497	28·11
11	9	1023	1196	1282	1368	1454	1540	28·72
12	0	1056	1232	1320	1408	1496	1584	29·33
12	3	1089	1269	1359	1449	1538	1628	29·94
12	6	1123	1306	1398	1490	1581	1673	30·55
12	9	1157	1344	1438	1531	1625	1718	31·17
13	0	1192	1382	1478	1573	1668	1764	31·78
13	3	1227	1421	1518	1615	1713	1810	32·39
13	6	1262	1460	1559	1658	1757	1856	33·
13	9	1298	1500	1601	1702	1802	1903	33·61

BATTER OF SLOPES $1\frac{1}{2}$ TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
14	0	1335	1540	1643	1745	1848	1951	34·22
14	3	1372	1581	1685	1790	1894	1999	34·83
14	6	1409	1622	1728	1834	1941	2047	35·44
14	9	1447	1663	1771	1879	1988	2096	36·06
15	0	1485	1705	1815	1925	2035	2145	36·67
15	3	1524	1747	1859	1971	2083	2195	37·28
15	6	1563	1790	1904	2018	2131	2245	37·89
15	9	1603	1834	1949	2065	2180	2296	38·50
16	0	1643	1877	1995	2112	2229	2347	39·11
16	3	1683	1922	2041	2160	2279	2398	39·72
16	6	1724	1966	2087	2208	2329	2450	40·33
16	9	1766	2011	2134	2257	2380	2503	40·94
17	0	1808	2057	2182	2306	2431	2556	41·55
17	3	1850	2103	2230	2356	2483	2609	42·17
17	6	1893	2150	2278	2406	2535	2663	42·78
17	9	1936	2197	2327	2457	2587	2717	43·39
18	0	1980	2244	2376	2508	2640	2772	44·
18	3	2024	2292	2426	2560	2693	2827	44·61
18	6	2069	2340	2476	2612	2747	2883	45·22
18	9	2114	2389	2527	2664	2802	2939	45·83
19	0	2160	2438	2578	2717	2856	2996	46·44
19	3	2206	2488	2629	2770	2912	3053	47·06
19	6	2252	2538	2681	2824	2967	3110	47·67
19	9	2299	2589	2734	2879	3023	3168	48·28
20	0	2347	2640	2787	2933	3080	3227	48·89
20	3	2395	2692	2840	2989	3137	3286	49·50
20	6	2443	2744	2894	3044	3195	3345	50·11
20	9	2492	2796	2948	3100	3253	3405	50·72

Batter of Slopes $1\frac{1}{2}$ to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
21	0	2541	2849	3003	3157	3311	3465	51·33
21	3	2591	2902	3058	3214	3370	3526	51·94
21	6	2641	2956	3114	3272	3429	3587	52·55
21	9	2692	3011	3170	3330	3489	3649	53·17
22	0	2743	3065	3227	3388	3549	3711	53·78
22	3	2794	3121	3284	3447	3610	3773	54·39
22	6	2846	3176	3341	3506	3671	3836	55·
22	9	2899	3232	3399	3566	3733	3900	55·61
23	0	2952	3289	3458	3626	3795	3964	56·22
23	3	3005	3346	3517	3687	3858	4028	56·83
23	6	3059	3404	3576	3748	3921	4093	57·44
23	9	3113	3462	3636	3810	3984	4158	58·06
24	0	3168	3520	3696	3872	4048	4224	58·67
24	3	3223	3579	3757	3935	4112	4290	59·28
24	6	3279	3638	3818	3998	4177	4357	59·89
24	9	3335	3698	3880	4061	4243	4424	60·50
25	0	3392	3758	3942	4125	4308	4492	61·11
25	3	3449	3819	4004	4189	4375	4560	61·72
25	6	3506	3880	4067	4254	4441	4628	62·33
25	9	3564	3942	4131	4320	4508	4697	62·94
26	0	3623	4004	4195	4385	4576	4767	63·55
26	3	3682	4067	4259	4452	4644	4837	64·17
26	6	3741	4130	4324	4518	4713	4907	64·78
26	9	3801	4193	4389	4585	4782	4978	65·39
27	0	3861	4257	4455	4653	4851	5049	66·
27	3	3922	4321	4521	4721	4921	5121	66·61
27	6	3983	4386	4588	4790	4991	5193	67·22
27	9	4045	4452	4655	4859	5062	5266	67·83

Batter of Slopes 1½ to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
28	0	4107	4517	4723	4928	5133	5339	68·44
28	3	4169	4584	4791	4998	5205	5412	69·06
28	6	4232	4650	4859	5068	5277	5486	69·67
28	9	4296	4717	4928	5139	5350	5561	70·28
29	0	4360	4785	4998	5210	5423	5636	70·89
29	3	4424	4853	5068	5282	5497	5711	71·50
29	6	4489	4922	5138	5354	5571	5787	72·11
29	9	4554	4991	5209	5427	5645	5863	72·72
30	0	4620	5060	5280	5500	5720	5940	73·33
30	3	4686	5130	5352	5574	5795	6017	73·94
30	6	4753	5200	5324	5648	5871	6095	74·55
30	9	4820	5271	5497	5722	5948	6173	75·17
31	0	4888	5342	5570	5797	6024	6252	75·78
31	3	4956	5414	5643	5872	6102	6331	76·39
31	6	5024	5486	5717	5948	6179	6410	77·
31	9	5093	5559	5792	6025	6257	6490	77·61
32	0	5163	5632	5867	6101	6336	6571	78·22
32	3	5233	5706	5942	6179	6415	6652	78·83
32	6	5303	5780	6018	6256	6495	6733	79·44
32	9	5374	5854	6094	6334	6575	6815	80·06
33	0	5445	5929	6171	6413	6655	6897	80·67
33	3	5517	6004	6248	6492	6736	6980	81·28
33	6	5589	6080	6326	6572	6817	7063	81·89
33	9	5662	6157	6404	6652	6899	7147	82·50
34	0	5735	6233	6483	6732	6981	7231	83·11
34	3	5808	6311	6562	6813	7064	7315	83·72
34	6	5882	6388	6641	6894	7147	7400	84·33
34	9	5957	6466	6721	6976	7231	7486	84·94

Batter of Slopes 1½ to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	23 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
35	0	6032	6545	6802	7058	7315	7572	85·55
35	3	6107	6624	6883	7141	7400	7658	86·17
35	6	6183	6704	6964	7224	7485	7745	86·78
35	9	6259	6784	7046	7308	7570	7832	87·39
36	0	6336	6864	7128	7392	7656	7920	88·
36	3	6413	6945	7211	7477	7742	8008	88·61
36	6	6491	7026	7294	7562	7829	8097	89·22
36	9	6569	7108	7378	7647	7917	8186	89·83
37	0	6648	7190	7462	7733	8004	8276	90·44
37	3	6727	7273	7546	7819	8093	8366	91·06
37	6	6806	7356	7631	7906	8181	8456	91·67
37	9	6886	7440	7717	7994	8270	8547	92·28
38	0	6967	7524	7803	8081	8360	8639	92·89
38	3	7048	7609	7889	8170	8450	8731	93·50
38	6	7129	7694	7976	8258	8541	8823	94·11
38	9	7211	7779	8063	8347	8632	8916	94·72
39	0	7293	7865	8151	8437	8723	9009	95·33
39	3	7376	7951	8239	8527	8815	9103	95·94
39	6	7459	8038	8328	8618	8907	9197	96·55
39	9	7543	8126	8417	8709	9000	9292	97·17
40	0	7627	8213	8507	8800	9093	9387	97·78
40	3	7711	8302	8597	8892	9187	9482	98·39
40	6	7796	8390	8687	8984	9281	9578	99·
40	9	7882	8479	8778	9077	9376	9675	99·61
41	0	7968	8569	8870	9170	9471	9772	100·22
41	3	8054	8659	8962	9264	9567	9869	100·83
41	6	8141	8750	9054	9358	9663	9967	101·44
41	9	8228	8841	9147	9453	9759	10065	102·06

Batter of Slopes 1½ to 1.

Depths of Cutting.		Breadths at Formation-Level. 18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	One Central Foot in breadth.
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
42	0	8316	8932	9240	9548	9856	10164	102·67
42	3	8404	9024	9334	9644	9953	10263	103·28
42	6	8493	9116	9428	9740	10051	10363	103·89
42	9	8582	9209	9523	9836	10150	10463	104·50
43	0	8672	9302	9618	9933	10248	10564	105·11
43	3	8762	9396	9713	10030	10348	10665	105·72
43	6	8852	9490	9809	10128	10447	10766	106·33
43	9	8943	9585	9906	10227	10547	10868	106·94
44	0	9035	9680	10003	10325	10648	10971	107·55
44	3	9127	9776	10100	10425	10749	11074	108·17
44	6	9219	9872	10198	10524	10851	11177	108·78
44	9	9312	9968	10296	10624	10953	11281	109·39
45	0	9405	10065	10395	10725	11055	11385	110·
45	3	9499	10162	10494	10826	11158	11490	110·61
45	6	9593	10260	10594	10928	11261	11595	111·22
45	9	9688	10359	10694	11030	11365	11701	111·83
46	0	9783	10457	10795	11132	11469	11807	112·44
46	3	9878	10557	10896	11235	11574	11913	113·06
46	6	9974	10656	10997	11338	11679	12020	113·67
46	9	10071	10756	11099	11442	11785	12128	114·28
47	0	10168	10857	11202	11546	11891	12236	114·89
47	3	10265	10958	11305	11651	11998	12344	115·50
47	6	10363	11060	11408	11756	12105	12453	116·11
47	9	10461	11162	11512	11862	12212	12562	116·72
48	0	10560	11264	11616	11968	12320	12672	117·33
48	3	10659	11367	11721	12075	12428	12782	117·94
48	6	10759	11470	11826	12182	12537	12893	118·55
48	9	10859	11574	11932	12289	12647	13004	119·17

Batter of Slopes 1½ to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
49	0	10960	11678	12038	12397	12756	13116	119·78
49	3	11061	11783	12144	12505	12867	13228	120·39
49	6	11162	11888	12251	12614	12977	13340	121·
49	9	11264	11994	12359	12724	13088	13453	121·61
50	0	11367	12100	12467	12833	13200	13567	122·22
50	3	11470	12207	12575	12944	13312	13681	122·83
50	6	11573	12314	12684	13054	13425	13795	123·44
50	9	11677	12421	12793	13165	13538	13910	124·06
51	0	11781	12529	12903	13277	13651	14025	124·67
51	3	11886	12637	13013	13389	13765	14141	125·28
51	6	11991	12746	13124	13502	13879	14257	125·89
51	9	12097	12856	13235	13615	13994	14374	126·50
52	0	12203	12965	13347	13728	14109	14491	127·11
52	3	12309	13076	13459	13842	14225	14608	127·72
52	6	12416	13186	13571	13956	14341	14726	128·33
52	9	12524	13297	13684	14071	14458	14845	128·94
53	0	12632	13409	13798	14186	14575	14964	129·55
53	3	12740	13521	13912	14302	14693	15083	130·17
53	6	12849	13634	14026	14418	14811	15203	130·78
53	9	12958	13747	14141	14535	14929	15323	131·39
54	0	13068	13860	14256	14652	15048	15444	132·
54	3	13178	13974	14372	14770	15167	15565	132·61
54	6	13289	14088	14488	14888	15287	15687	133·22
54	9	13400	14203	14605	15006	15408	15809	133·83
55	0	13512	14318	14722	15125	15528	15932	134·44
55	3	13624	14434	14839	15244	15650	16055	135·06
55	6	13736	14550	14957	15364	15771	16178	135·67
55	9	13849	14667	15076	15485	15893	16302	136·28

BATTER OF SLOPES $1\frac{1}{2}$ TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
56	0	13963	14784	15195	15605	16016	16427	136·89
56	3	14077	14902	15314	15727	16139	16552	137·50
56	6	14191	15020	15434	15848	16263	16677	138·11
56	9	14306	15138	15554	15970	16387	16803	138·72
57	0	14421	15257	15675	16093	16511	16929	139·33
57	3	14537	15376	15796	16216	16636	17056	139·94
57	6	14653	15496	15918	16340	16761	17183	140·55
57	9	14770	15617	16040	16464	16887	17311	141·17
58	0	14887	15737	16163	16588	17013	17439	141·78
58	3	15004	15859	16286	16713	17140	17567	142·39
58	6	15122	15980	16409	16838	17267	17696	143·
58	9	15241	16102	16533	16964	17395	17826	143·61
59	0	15360	16225	16658	17090	17523	17956	144·22
59	3	15479	16348	16783	17217	17652	18086	144·83
59	6	15599	16472	16908	17344	17781	18217	145·44
59	9	15719	16596	17034	17472	17910	18348	146·06
60	0	15840	16720	17160	17600	18040	18480	146·67
60	3	15961	16845	17287	17729	18170	18612	147·28
60	6	16083	16970	17414	17858	18301	18745	147·89
60	9	16205	17096	17542	17987	18433	18878	148·50
61	0	16328	17222	17670	18117	18564	19012	149·11
61	3	16451	17349	17798	18247	18697	19146	149·72
61	6	16574	17476	17927	18378	18829	19280	150·33
61	9	16698	17604	18057	18510	18962	19415	150·94
62	0	16823	17732	18187	18641	19096	19551	151·55
62	3	16948	17861	18317	18774	19230	19687	152·17
62	6	17073	17990	18448	18906	19365	19823	152·78
62	9	17199	18119	18579	19039	19500	19960	153·39

Batter of Slopes 1½ to 1.

Depths of Cutting. Ft.	in.	Breadths at Formation-Level. 18 feet. cub. yds.	24 feet cub. yds.	27 feet. cub. yds.	30 feet. cub. yds.	33 feet. cub. yds.	36 feet. cub. yds.	One Central Foot in breadth. cub. yards.
63	0	17325	18249	18711	19173	19635	20097	154·
63	3	17452	18379	18843	19307	19771	20235	154·61
63	6	17579	18510	18976	19442	19907	20373	155·22
63	9	17707	18642	19109	19577	20044	20512	155·83
64	0	17835	18773	19243	19712	20181	20651	156·44
64	3	17963	18906	19377	19848	20319	20790	157·06
64	6	18092	19038	19511	19984	20457	20930	157·67
64	9	18222	19171	19646	20121	20596	21071	158·28
65	0	18352	19305	19782	20258	20735	21212	158·89
65	3	18482	19439	19918	20396	20875	21353	159·50
65	6	18613	19574	20054	20534	21015	21495	160·11
65	9	18744	19709	20191	20673	21155	21637	160·72
66	0	18876	19844	20328	20812	21296	21780	161·33
66	3	19008	19980	20466	20952	21437	21923	161·94
66	6	19141	20116	20604	21092	21579	22067	162·55
66	9	19274	20253	20743	21232	21722	22211	163·17
67	0	19408	20390	20882	21373	21864	22356	163·78
67	3	19542	20528	21021	21514	22008	22501	164·39
67	6	19676	20666	21161	21656	22151	22646	165·
67	9	19811	20805	21302	21799	22295	22792	165·61
68	0	19947	20944	21443	21941	22440	22939	166·22
68	3	20083	21084	21584	22085	22585	23086	166·83
68	6	20219	21224	21726	22228	22731	23233	167·44
68	9	20356	21364	21868	22372	22877	23381	168·06
69	0	20493	21505	22011	22517	23023	23529	168·67
69	3	20631	21646	22154	22662	23170	23678	169·28
69	6	20769	21788	22298	22808	23317	23827	169·89
69	9	20908	21931	22442	22954	23465	23977	170·50
70	0	21047	22073	22587	23100	23613	24127	171·11

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TABLE IV.

Batter of Slopes 1¾ to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
1	0	48	63	70	78	85	92	2·44
1	3	62	80	89	98	108	117	3·06
1	6	76	98	109	120	131	142	3·67
1	9	90	116	129	141	154	167	4·28
2	0	105	134	149	164	178	193	4·89
2	3	121	154	170	187	203	220	5·50
2	6	137	173	192	210	228	247	6·11
2	9	153	194	214	234	254	274	6·72
3	0	171	215	237	259	281	303	7·33
3	3	188	236	260	284	307	331	7·94
3	6	206	258	283	309	335	360	8·55
3	9	225	280	308	335	363	390	9·17
4	0	244	303	332	362	391	420	9·78
4	3	264	327	358	389	420	451	10·39
4	6	285	351	384	417	450	483	11·
4	9	306	375	410	445	480	515	11·61
5	0	327	400	437	474	510	547	12·22
5	3	349	426	464	503	541	580	12·83
5	6	371	452	492	533	573	613	13·44
5	9	394	479	521	563	605	647	14·06
6	0	418	506	550	594	638	682	14·67
6	3	442	534	580	625	671	717	15·28
6	6	467	562	610	657	705	753	15·89
6	9	492	591	640	690	739	789	16·50

BATTER OF SLOPES $1\frac{3}{4}$ TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
7	0	518	620	672	723	774	826	17·11
7	3	544	650	703	757	810	863	17·72
7	6	571	681	736	791	846	901	18·33
7	9	598	712	768	825	882	939	18·94
8	0	626	743	802	860	919	978	19·55
8	3	654	775	836	896	957	1017	20·17
8	6	683	808	870	932	995	1057	20·78
8	9	713	841	905	969	1033	1098	21·39
9	0	743	875	941	1007	1073	1139	22·
9	3	773	909	977	1044	1112	1180	22·61
9	6	804	943	1013	1083	1152	1222	23·22
9	9	836	979	1050	1122	1193	1265	23·83
10	0	868	1014	1088	1161	1234	1308	24·44
10	3	900	1051	1126	1201	1276	1351	25·06
10	6	934	1088	1165	1242	1319	1396	25·67
10	9	967	1125	1204	1283	1362	1440	26·28
11	0	1002	1163	1244	1324	1405	1486	26·89
11	3	1036	1201	1284	1366	1449	1531	27·50
11	6	1072	1240	1325	1409	1493	1578	28·11
11	9	1108	1280	1366	1452	1538	1625	28·72
12	0	1144	1320	1408	1496	1584	1672	29·33
12	3	1181	1361	1450	1540	1630	1720	29·94
12	6	1218	1402	1493	1585	1677	1768	30·55
12	9	1256	1443	1537	1630	1724	1817	31·17
13	0	1295	1486	1581	1676	1772	1867	31·78
13	3	1334	1528	1626	1723	1820	1917	32·39
13	6	1374	1572	1671	1770	1869	1968	33·
13	9	1414	1615	1716	1817	1918	2019	33·61

Batter of Slopes 1¾ to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
14	0	1454	1660	1762	1865	1968	2070	34·22
14	3	1496	1705	1809	1914	2018	2123	34·83
14	6	1537	1750	1856	1968	2069	2175	35·44
14	9	1580	1796	1904	2012	2121	2229	36·06
15	0	1623	1843	1953	2063	2173	2283	36·67
15	3	1666	1890	2001	2113	2225	2337	37·28
15	6	1710	1937	2051	2164	2278	2392	37·89
15	9	1754	1985	2101	2216	2332	2447	38·50
16	0	1799	2034	2151	2268	2386	2503	39·11
16	3	1845	2083	2202	2321	2440	2560	39·72
16	6	1891	2133	2254	2375	2496	2617	40·33
16	9	1937	2183	2306	2429	2551	2674	40·94
17	0	1984	2234	2358	2483	2608	2782	41·55
17	3	2032	2285	2411	2538	2664	2791	42·17
17	6	2080	2337	2465	2593	2722	2850	42·78
17	9	2129	2389	2519	2649	2780	2910	43·39
18	0	2178	2442	2574	2706	2838	2970	44·
18	3	2228	2495	2629	2763	2897	3031	44·61
18	6	2278	2549	2685	2821	2956	3092	45·22
18	9	2329	2604	2741	2879	3016	3154	45·83
19	0	2380	2659	2798	2938	3077	3216	46·44
19	3	2432	2715	2856	2997	3138	3279	47·06
19	6	2485	2771	2914	3057	3200	3343	47·67
19	9	2538	2827	2972	3117	3262	3407	48·28
20	0	2591	2884	3031	3178	3324	3471	48·89
20	3	2645	2942	3091	3239	3388	3536	49·50
20	6	2700	3000	3151	3301	3451	3602	50·11
20	9	2755	3059	3211	3364	3516	3668	50·72

BATTER OF SLOPES $1\frac{3}{4}$ TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
21	0	2811	3119	3273	3427	3581	3735	51·33
21	3	2867	3178	3334	3490	3646	3802	51·94
21	6	2923	3239	3396	3554	3712	3869	52·55
21	9	2981	3300	3459	3619	3778	3938	53·17
22	0	3038	3361	3522	3684	3845	4006	53·78
22	3	3097	3423	3586	3749	3913	4076	54·39
22	6	3156	3486	3651	3816	3981	4146	55·
22	9	3215	3549	3716	3882	4049	4216	55·61
23	0	3275	3612	3781	3950	4118	4287	56·22
23	3	3335	3676	3847	4017	4188	4358	56·83
23	6	3396	3741	3913	4086	4258	4430	57·44
23	9	3458	3806	3980	4155	4329	4503	58·06
24	0	3520	3872	4048	4224	4400	4576	58·67
24	3	3583	3938	4116	4294	4472	4650	59·28
24	6	3646	4005	4185	4364	4544	4724	59·89
24	9	3709	4072	4254	4435	4617	4798	60·50
25	0	3774	4140	4324	4507	4690	4874	61·11
25	3	3838	4209	4394	4579	4764	4949	61·72
25	6	3904	4278	4465	4652	4839	5026	62·33
25	9	3969	4347	4536	4725	4914	5102	62·94
26	0	4036	4417	4608	4798	4989	5180	63·55
26	3	4103	4488	4680	4873	5065	5258	64·17
26	6	4170	4559	4753	4947	5142	5336	64·78
26	9	4238	4630	4827	5023	5219	5415	65·39
27	0	4307	4703	4901	5099	5297	5495	66·
27	3	4376	4775	4975	5175	5375	5575	66·61
27	6	4445	4848	5050	5252	5453	5655	67·22
27	9	4515	4922	5126	5329	5533	5736	67·83

BATTER OF SLOPES 1¾ TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
28	0	4586	4996	5202	5407	5612	5818	68·44
28	3	4657	5071	5278	5486	5693	5900	69·06
28	6	4729	5147	5356	5565	5774	5983	69·67
28	9	4801	5223	5433	5644	5855	6066	70·28
29	0	4874	5299	5512	5724	5937	6150	70·89
29	3	4947	5376	5590	5805	6019	6234	71·50
29	6	5021	5453	5670	5886	6102	6319	72·11
29	9	5095	5531	5750	5968	6186	6404	72·72
30	0	5170	5610	5830	6050	6270	6490	73·33
30	3	5245	5689	5911	6133	6355	6576	73·94
30	6	5321	5769	5992	6216	6440	6663	74·55
30	9	5398	5849	6074	6300	6525	6751	75·17
31	0	5475	5930	6157	6384	6612	6839	75·78
31	3	5553	6011	6240	6469	6698	6928	76·39
31	6	5631	6093	6324	6555	6786	7017	77·
31	9	5709	6175	6408	6641	6873	7106	77·61
32	0	5788	6258	6492	6727	6962	7196	78·22
32	3	5868	6341	6578	6814	7051	7287	78·83
32	6	5948	6425	6663	6902	7140	7378	79·44
32	9	6029	6510	6750	6990	7230	7470	80·06
33	0	6111	6595	6837	7079	7321	7563	80·67
33	3	6192	6680	6924	7168	7412	7655	81·28
33	6	6275	6766	7012	7257	7503	7749	81·89
33	9	6358	6853	7100	7348	7595	7843	82·50
34	0	6441	6940	7189	7438	7688	7937	83·11
34	3	6525	7027	7279	7530	7781	8032	83·72
34	6	6610	7116	7369	7622	7875	8128	84·33
34	9	6695	7204	7459	7714	7969	8224	84·94

Batter of Slopes 1¾ to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds	cub. yds.	cub. yds.	cub. yds.	cub. yards.
35	0	6780	7294	7550	7807	8064	8320	85·55
35	3	6866	7383	7642	7900	8159	8417	86·17
35	6	6953	7474	7734	7994	8255	8515	86·78
35	9	7040	7565	7827	8089	8351	8613	87·39
36	0	7128	7656	7920	8184	8448	8712	88·
36	3	7216	7748	8014	8280	8545	8811	88·61
36	6	7305	7840	8108	8376	8643	8911	89·22
36	9	7394	7933	8203	8472	8742	9011	89·83
37	0	7484	8027	8298	8570	8841	9112	90·44
37	3	7575	8121	8394	8667	8941	9214	91·06
37	6	7666	8216	8491	8766	9041	9316	91·67
37	9	7757	8311	8588	8864	9141	9418	92·28
38	0	7849	8406	8685	8964	9242	9521	92·89
38	3	7942	8503	8783	9064	9344	9625	93·50
38	6	8035	8599	8882	9164	9446	9729	94·11
38	9	8128	8697	8981	9265	9549	9833	94·72
39	0	8223	8795	9081	9367	9653	9939	95·33
39	3	8317	8893	9181	9469	9756	10044	95·94
39	6	8412	8992	9281	9571	9861	10150	96·55
39	9	8508	9091	9383	9674	9966	10257	97·17
40	0	8604	9191	9484	9778	10071	10364	97·78
40	3	8701	9292	9587	9882	10177	10472	98·39
40	6	8799	9393	9690	9987	10284	10581	99·
40	9	8897	9494	9793	10092	10391	10690	99·61
41	0	8995	9596	9897	10198	10498	10799	100·22
41	3	9094	9699	10001	10304	10606	10909	100·83
41	6	9193	9802	10106	10411	10715	11019	101·44
41	9	9293	9906	10212	10518	10824	11130	102·06

BATTER OF SLOPES $1\frac{3}{4}$ TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
42	0	9394	10010	10318	10626	10934	11242	102·67
42	3	9495	10115	10425	10734	11044	11354	103·28
42	6	9597	10220	10532	10843	11155	11467	103·89
42	9	9699	10326	10639	10953	11266	11580	104·50
43	0	9802	10432	10748	11063	11378	11694	105·11
43	3	9905	10539	10856	11174	11491	11808	105·72
43	6	10009	10647	10966	11285	11604	11923	106·33
43	9	10113	10755	11075	11396	11717	12038	106·94
44	0	10218	10863	11186	11508	11831	12154	107·55
44	3	10323	10972	11297	11621	11946	12270	108·17
44	6	10429	11082	11408	11734	12061	12387	108·78
44	9	10536	11192	11520	11848	12176	12505	109·39
45	0	10643	11303	11633	11963	12293	12623	110·
45	3	10750	11414	11746	12077	12409	12741	110·61
45	6	10858	11525	11859	12193	12526	12860	111·22
45	9	10967	11638	11973	12309	12644	12980	111·83
46	0	11076	11750	12088	12425	12762	13100	112·44
46	3	11185	11864	12203	12542	12881	13220	113·06
46	6	11296	11978	12319	12660	13001	13342	113·67
46	9	11406	12092	12435	12778	13121	13463	114·28
47	0	11518	12207	12552	12896	13241	13586	114·89
47	3	11629	12322	12669	13015	13362	13708	115·50
47	6	11742	12438	12787	13135	13483	13832	116·11
47	9	11855	12555	12905	13255	13605	13956	116·72
48	0	11968	12672	13024	13376	13728	14080	117·33
48	3	12082	12790	13143	13497	13851	14205	117·94
48	6	12196	12908	13263	13619	13975	14330	118·55
48	9	12311	13026	13384	13741	14099	14456	119·17

BATTER OF SLOPES $1\frac{3}{4}$ TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
49	0	12427	13146	13505	13864	14224	14583	119·78
49	3	12543	13265	13627	13988	14349	14710	120·39
49	6	12660	13386	13749	14112	14475	14838	121·
49	9	12777	13506	13871	14236	14601	14966	121·61
50	0	12894	13628	13994	14361	14728	15094	122·22
50	3	13013	13750	14118	14487	14855	15224	122·83
50	6	13131	13872	14242	14613	14983	15353	123·44
50	9	13251	13995	14367	14739	15112	15484	124·06
51	0	13371	14119	14493	14867	15241	15615	124·67
51	3	13491	14243	14618	14994	15370	15746	125·28
51	6	13612	14367	14745	15122	15500	15878	125·89
51	9	13733	14492	14872	15251	15631	16010	126·50
52	0	13855	14618	14999	15380	15762	16143	127·11
52	3	13978	14744	15127	15510	15893	16277	127·72
52	6	14101	14871	15256	15641	16026	16411	128·33
52	9	14224	14998	15385	15772	16158	16545	128·94
53	0	14348	15126	15514	15903	16292	16680	129·55
53	3	14473	15254	15644	16035	16425	16816	130·17
53	6	14598	15383	15775	16167	16560	16952	130·78
53	9	14724	15512	15906	16300	16695	17089	131·39
54	0	14850	15642	16038	16434	16830	17226	132·
54	3	14977	15772	16170	16568	16966	17364	132·61
54	6	15104	15903	16303	16703	17102	17502	133·22
54	9	15232	16035	16436	16838	17239	17641	133·83
55	0	15360	16167	16570	16974	17377	17780	134·44
55	3	15489	16300	16705	17110	17515	17920	135·06
55	6	15619	16433	16840	17247	17654	18061	135·67
55	9	15749	16566	16975	17384	17793	18202	136·28

BATTER OF SLOPES 1¾ TO 1.

Depths of Cutting		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet	24 feet	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
56	0	15879	16700	17111	17522	17932	18343	136·89
56	3	16010	16835	17248	17660	18073	18485	137·50
56	6	16142	16970	17385	17799	18213	18628	138·11
56	9	16274	17106	17522	17939	18355	18771	138·72
57	0	16407	17243	17661	18079	18497	18915	139·33
57	3	16540	17379	17799	18219	18639	19059	139·94
57	6	16673	17517	17938	18360	18782	19203	140·55
57	9	16808	17655	18078	18502	18925	19349	141·17
58	0	16942	17793	18218	18644	19069	19494	141·78
58	3	17078	17932	18359	18786	19214	19641	142·39
58	6	17214	18072	18501	18930	19359	19788	143·
58	9	17350	18212	18643	19073	19504	19935	143·61
59	0	17487	18352	18785	19218	19650	20083	144·22
59	3	17624	18493	18928	19362	19797	20231	144·83
59	6	17762	18635	19071	19508	19944	20380	145·44
59	9	17901	18777	19215	19654	20092	20530	146·06
60	0	18040	18920	19360	19800	20240	20680	146·67
60	3	18180	19063	19505	19947	20389	20831	147·28
60	6	18320	19207	19651	20094	20538	20982	147·89
60	9	18460	19351	19797	20242	20688	21133	148·50
61	0	18602	19496	19944	20391	20838	21286	149·11
61	3	18743	19642	20091	20540	20989	21438	149·72
61	6	18886	19788	20239	20690	21141	21592	150·33
61	9	19028	19934	20387	20840	21293	21745	150·94
62	0	19172	20081	20536	20990	21445	21900	151·55
62	3	19316	20229	20685	21142	21598	22055	152·17
62	6	19460	20377	20835	21293	21752	22210	152·78
62	9	19605	20525	20986	21446	21906	22366	153·39

BATTER OF SLOPES $1\frac{3}{4}$ TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
63	0	19751	20675	21137	21599	22061	22523	154·
63	3	19897	20824	21288	21752	22216	22680	154·61
63	6	20043	20974	21440	21906	22371	22837	155·22
63	9	20190	21125	21593	22060	22528	22995	155·83
64	0	20338	21276	21746	22215	22684	23154	156·44
64	3	20486	21428	21899	22371	22842	23313	157·06
64	6	20635	21581	22054	22527	23000	23473	157·67
64	9	20784	21734	22208	22683	23158	23633	158·28
65	0	20934	21887	22364	22840	23317	23794	158·89
65	3	21084	22041	22519	22998	23476	23955	159·50
65	6	21235	22195	22676	23156	23636	24117	160·11
65	9	21386	22350	22833	23315	23797	24279	160·72
66	0	21538	22506	22990	23474	23958	24442	161·33
66	3	21690	22662	23148	23634	24120	24605	161·94
66	6	21843	22819	23306	23794	24282	24769	162·55
66	9	21997	22976	23465	23955	24444	24934	163·17
67	0	22151	23134	23625	24116	24608	25099	163·78
67	3	22306	23292	23785	24278	24771	25265	164·39
67	6	22461	23451	23946	24441	24936	25431	165·
67	9	22616	23610	24107	24604	25100	25597	165·61
68	0	22772	23770	24268	24767	25266	25764	166·22
68	3	22929	23930	24431	24931	25432	25932	166·83
68	6	23086	24091	24593	25096	25598	26100	167·44
68	9	23244	24253	24757	25261	25765	26269	168·06
69	0	23403	24415	24921	25427	25933	26439	168·67
69	3	23561	24577	25085	25593	26101	26608	169·28
69	6	23721	24740	25250	25759	26269	26779	169·89
69	9	23881	24904	25415	25927	26438	26950	170·50
70	0	24041	25068	25581	26094	26608	27121	171·11

TABLE V.

Batter of Slopes 2 to 1.

Depths of Cutting. Ft.	in.	Breadths at Formation-Level. 18 feet. cub. yds.	24 feet. cub. yds.	27 feet. cub. yds.	30 feet. cub. yds.	33 feet. cub. yds.	36 feet. cub. yds.	One Central Foot in breadth. cub. yards.
1	0	49	64	71	78	86	93	2·44
1	3	63	81	90	99	109	118	3·06
1	6	77	99	110	121	132	143	3·67
1	9	92	118	130	143	156	169	4·28
2	0	108	137	152	166	181	196	4·89
2	3	124	157	173	190	206	223	5·50
2	6	141	177	196	214	232	251	6·11
2	9	158	198	218	239	259	279	6·72
3	0	176	220	242	264	286	308	7·33
3	3	195	242	266	290	314	338	7·94
3	6	214	265	291	317	342	368	8·55
3	9	234	289	316	344	371	399	9·17
4	0	254	313	342	372	401	430	9·78
4	3	275	338	369	400	431	462	10·39
4	6	297	363	396	429	462	495	11·
4	9	319	389	424	459	493	528	11·61
5	0	342	416	452	489	526	562	12·22
5	3	366	443	481	520	558	597	12·83
5	6	390	471	511	551	592	632	13·44
5	9	415	499	541	583	626	668	14·06
6	0	440	528	572	616	660	704	14·67
6	3	466	558	603	649	695	741	15·28
6	6	493	588	636	683	731	779	15·89
6	9	520	619	668	718	767	817	16·50

Batter of Slopes 2 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
7	0	548	650	702	753	804	856	17·11
7	3	576	682	735	789	842	895	17·72
7	6	605	715	770	825	880	935	18·33
7	9	635	748	805	862	919	976	18·94
8	0	665	782	841	900	958	1017	19·55
8	3	696	817	877	938	998	1059	20·17
8	6	727	852	914	977	1039	1101	20·78
8	9	759	888	952	1016	1080	1144	21·39
9	0	792	924	990	1056	1122	1188	22·
9	3	825	961	1029	1097	1164	1232	22·61
9	6	859	999	1068	1138	1208	1277	23·22
9	9	894	1037	1108	1180	1251	1323	23·83
10	0	929	1076	1149	1222	1296	1369	24·44
10	3	965	1115	1190	1265	1341	1416	25·06
10	6	1001	1155	1232	1309	1386	1463	25·67
10	9	1038	1196	1274	1353	1432	1511	26·28
11	0	1076	1237	1318	1398	1479	1560	26·89
11	3	1114	1279	1361	1444	1526	1609	27·50
11	6	1153	1321	1406	1490	1574	1659	28·11
11	9	1192	1364	1450	1537	1623	1709	28·72
12	0	1232	1408	1496	1584	1672	1760	29·33
12	3	1273	1452	1542	1632	1722	1812	29·94
12	6	1314	1497	1589	1681	1772	1864	30·55
12	9	1356	1543	1636	1730	1823	1917	31·17
13	0	1398	1589	1684	1780	1875	1970	31·78
13	3	1441	1636	1733	1830	1927	2024	32·39
13	6	1485	1683	1782	1881	1980	2079	33·
13	9	1529	1731	1832	1933	2033	2134	33·61

Batter of Slopes 2 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
14	0	1574	1780	1882	1985	2088	2190	34·22
14	3	1620	1829	1933	2038	2142	2247	34·83
14	6	1666	1879	1985	2091	2198	2304	35·44
14	9	1713	1929	2037	2145	2254	2362	36·06
15	0	1760	1980	2090	2200	2310	2420	36·67
15	3	1808	2032	2143	2255	2367	2479	37·28
15	6	1857	2084	2198	2311	2425	2539	37·89
15	9	1906	2137	2252	2368	2483	2599	38·50
16	0	1956	2190	2308	2425	2542	2660	39·11
16	3	2006	2244	2363	2483	2602	2721	39·72
16	6	2057	2299	2420	2541	2662	2783	40·33
16	9	2109	2354	2477	2600	2723	2846	40·94
17	0	2161	2410	2535	2660	2784	2909	41·55
17	3	2214	2467	2593	2720	2846	2973	42·17
17	6	2267	2524	2652	2781	2909	3037	42·78
17	9	2321	2582	2712	2842	2972	3102	43·39
18	0	2376	2640	2772	2904	3036	3168	44·
18	3	2431	2699	2833	2967	3100	3234	44·61
18	6	2487	2759	2894	3030	3166	3301	45·22
18	9	2544	2819	2956	3094	3231	3369	45·83
19	0	2601	2880	3019	3158	3298	3437	46·44
19	3	2659	2941	3082	3223	3365	3506	47·06
19	6	2717	3003	3146	3289	3432	3575	47·67
19	9	2776	3066	3210	3355	3500	3645	48·28
20	0	2836	3129	3276	3422	3569	3716	48·89
20	3	2896	3193	3341	3490	3638	3787	49·50
20	6	2957	3257	3408	3558	3708	3859	50·11
20	9	3018	3322	3474	3627	3779	3931	50·72

BATTER OF SLOPES 2 TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
21	0	3080	3388	3542	3696	3850	4004	51·33
21	3	3143	3454	3610	3766	3922	4078	51·94
21	6	3206	3521	3679	3837	3994	4152	52·55
21	9	3270	3589	3748	3908	4067	4227	53·17
22	0	3334	3657	3818	3980	4141	4302	53·78
22	3	3399	3726	3889	4052	4215	4378	54·39
22	6	3465	3795	3960	4125	4290	4455	55·
22	9	3531	3865	4032	4199	4365	4532	55·61
23	0	3598	3936	4104	4273	4442	4610	56·22
23	3	3666	4007	4177	4348	4518	4689	56·83
23	6	3734	4079	4251	4423	4596	4768	57·44
23	9	3803	4151	4325	4499	4674	4848	58·06
24	0	3872	4224	4400	4576	4752	4928	58·67
24	3	3942	4298	4475	4653	4831	5009	59·28
24	6	4013	4372	4552	4731	4911	5091	59·89
24	9	4084	4447	4628	4810	4991	5173	60·50
25	0	4156	4522	4706	4889	5072	5256	61·11
25	3	4228	4598	4783	4969	5154	5339	61·72
25	6	4301	4675	4862	5049	5236	5423	62·33
25	9	4375	4752	4941	5130	5319	5508	62·94
26	0	4449	4830	5021	5212	5402	5593	63·55
26	3	4524	4909	5101	5294	5486	5679	64·17
26	6	4599	4988	5182	5377	5571	5765	64·78
26	9	4675	5068	5264	5460	5656	5852	65·39
27	0	4752	5148	5346	5544	5742	5940	66·
27	3	4829	5229	5429	5629	5828	6028	66·61
27	6	4907	5311	5512	5714	5916	6117	67·22
27	9	4986	5393	5596	5800	6003	6207	67·83

Batter of Slopes 2 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
28	0	5065	5476	5681	5886	6092	6297	68·44
28	3	5145	5559	5766	5973	6181	6388	69·06
28	6	5225	5643	5852	6061	6270	6479	69·67
28	9	5306	5728	5938	6149	6360	6571	70·28
29	0	5388	5813	6026	6238	6451	6664	70·89
29	3	5470	5899	6113	6328	6542	6757	71·50
29	6	5553	5985	6202	6418	6634	6851	72·11
29	9	5636	6072	6290	6509	6727	6945	72·72
30	0	5720	6160	6380	6600	6820	7040	73·33
30	3	5805	6248	6470	6692	6914	7136	73·94
30	6	5890	6337	6561	6785	7008	7232	74·55
30	9	5976	6427	6652	6878	7103	7329	75·17
31	0	6062	6517	6744	6972	7199	7426	75·78
31	3	6149	6608	6837	7066	7295	7524	76·39
31	6	6237	6699	6930	7161	7392	7623	77·
31	9	6325	6791	7024	7257	7489	7722	77·61
32	0	6414	6884	7118	7353	7588	7822	78·22
32	3	6504	6977	7213	7450	7686	7923	78·83
32	6	6594	7071	7309	7547	7786	8024	79·44
32	9	6685	7165	7405	7645	7886	8126	80·06
33	0	6776	7260	7502	7744	7986	8228	80·67
33	3	6868	7356	7599	7843	8087	8331	81·28
33	6	6961	7452	7698	7943	8189	8435	81·89
33	9	7054	7549	7796	8044	8291	8539	82·50
34	0	7148	7646	7896	8145	8394	8644	83·11
34	3	7242	7744	7995	8247	8498	8749	83·72
34	6	7337	7843	8096	8349	8602	8855	84·33
34	9	7433	7942	8197	8452	8707	8962	84·94

Batter of Slopes 2 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
35	0	7529	8042	8299	8556	8812	9069	85·55
35	3	7626	8143	8401	8660	8918	9177	86·17
35	6	7723	8244	8504	8765	9025	9285	86·78
35	9	7821	8346	8608	8870	9132	9394	87·39
36	0	7920	8448	8712	8976	9240	9504	88·
36	3	8019	8551	8817	9083	9348	9614	88·61
36	6	8119	8655	8922	9190	9458	9725	89·22
36	9	8220	8759	9028	9298	9567	9837	89·83
37	0	8321	8864	9135	9406	9678	9949	90·44
37	3	8423	8969	9242	9515	9789	10062	91·06
37	6	8525	9075	9350	9625	9900	10175	91·67
37	9	8628	9182	9458	9735	10012	10289	92·28
38	0	8732	9289	9568	9846	10125	10404	92·89
38	3	8836	9397	9677	9958	10238	10519	93·50
38	6	8941	9505	9788	10070	10352	10635	94·11
38	9	9046	9614	9898	10183	10467	10751	94·72
39	0	9152	9724	10010	10296	10582	10868	95·33
39	3	9259	9834	10122	10410	10698	10986	95·94
39	6	9366	9945	10235	10525	10814	11104	96·55
39	9	9474	10057	10348	10640	10931	11223	97·17
40	0	9582	10169	10462	10756	11049	11342	97·78
40	3	9691	10282	10577	10872	11167	11462	98·39
40	6	9801	10395	10692	10989	11286	11583	99·
40	9	9911	10509	10808	11107	11405	11704	99·61
41	0	10022	10624	10924	11225	11526	11826	100·22
41	3	10134	10739	11041	11344	11646	11949	100·83
41	6	10246	10855	11159	11463	11768	12072	101·44
41	9	10359	10971	11277	11583	11890	12196	102·06

Batter of Slopes 2 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
42	0	10472	11088	11396	11704	12012	12320	102·67
42	3	10586	11206	11515	11825	12135	12445	103·28
42	6	10701	11324	11636	11947	12259	12571	103·89
42	9	10816	11443	11756	12070	12383	12697	104·50
43	0	10932	11562	11878	12193	12508	12824	105·11
43	3	11048	11682	12000	12317	12634	12951	105·72
43	6	11165	11803	12122	12441	12760	13079	106·33
43	9	11283	11924	12245	12566	12887	13208	106·94
44	0	11401	12046	12369	12692	13014	13337	107·55
44	3	11520	12169	12493	12818	13142	13467	108·17
44	6	11639	12292	12618	12945	13271	13597	108·78
44	9	11759	12416	12744	13072	13400	13728	109·39
45	0	11880	12540	12870	13200	13530	13860	110·
45	3	12001	12665	12997	13329	13660	13992	110·61
45	6	12123	12791	13124	13458	13792	14125	111·22
45	9	12246	12917	13252	13588	13923	14259	111·83
46	0	12369	13044	13381	13718	14056	14393	112·44
46	3	12493	13171	13510	13849	14189	14528	113·06
46	6	12617	13299	13640	13981	14322	14663	113·67
46	9	12742	13428	13770	14113	14456	14799	114·28
47	0	12868	13557	13902	14246	14591	14936	114·89
47	3	12994	13687	14033	14380	14726	15073	115·50
47	6	13121	13817	14166	14514	14862	15211	116·11
47	9	13248	13948	14298	14649	14999	15349	116·72
48	0	13376	14080	14432	14784	15136	15488	117·33
48	3	13505	14212	14566	14920	15274	15628	117·94
48	6	13634	14345	14701	15057	15412	15768	118·55
48	9	13764	14479	14836	15194	15551	15909	119·17

Batter of Slopes 2 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds	cub. yds.	cub. yds.	cub. yards
49	0	13894	14613	14972	15332	15691	16050	119·78
49	3	14025	14748	15109	15470	15831	16192	120·39
49	6	14157	14883	15246	15609	15972	16335	121·
49	9	14289	15019	15384	15749	16113	16478	121·61
50	0	14422	15156	15522	15889	16256	16622	122·22
50	3	14556	15293	15661	16030	16398	16767	122·83
50	6	14690	15431	15801	16171	16542	16912	123·44
50	9	14825	15569	15941	16313	16686	17058	124·06
51	0	14960	15708	16082	16456	16830	17204	124·67
51	3	15096	15848	16223	16599	16975	17351	125·28
51	6	15233	15988	16366	16743	17121	17499	125·89
51	9	15370	16129	16508	16888	17267	17647	126·50
52	0	15508	16270	16652	17033	17414	17796	127·11
52	3	15646	16412	16795	17179	17562	17945	127·72
52	6	15785	16555	16940	17325	17710	18095	128·33
52	9	15925	16698	17085	17472	17859	18246	128·94
53	0	16065	16842	17231	17620	18008	18397	129·55
53	3	16206	16987	17377	17768	18158	18549	130·17
53	6	16347	17132	17524	17917	18309	18701	130·78
53	9	16489	17278	17672	18066	18460	18854	131·39
54	0	16632	17424	17820	18216	18612	19008	132·
54	3	16775	17571	17969	18367	18764	19162	132·61
54	6	16919	17719	18118	18518	18918	19317	133·22
54	9	17064	17867	18268	18670	19071	19473	133·83
55	0	17209	18016	18419	18822	19226	19629	134·44
55	3	17355	18165	18570	18975	19381	19786	135·06
55	6	17501	18315	18722	19129	19536	19943	135·67
55	9	17648	18466	18874	19283	19692	20101	136·28

Batter of Slopes 2 to 1.

Depths of Cutting		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet	24 feet	27 feet	30 feet	33 feet	36 feet	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
56	0	17796	18617	19028	19438	19849	20260	136·89
56	3	17944	18769	19181	19594	20006	20419	137·50
56	6	18093	18921	19336	19750	20164	20579	138·11
56	9	18242	19074	19490	19907	20323	20739	138·72
57	0	18392	19228	19646	20064	20482	20900	139·33
57	3	18543	19382	19802	20222	20642	21062	139·94
57	6	18694	19537	19959	20381	20802	21224	140·55
57	9	18846	19693	20116	20540	20963	21387	141·17
58	0	18998	19849	20274	20700	21125	21550	141·78
58	3	19151	20006	20433	20860	21287	21714	142·39
58	6	19305	20163	20592	21021	21450	21879	143·
58	9	19459	20321	20752	21183	21613	22044	143·61
59	0	19614	20480	20912	21345	21778	22210	144·22
59	3	19770	20639	21073	21508	21942	22377	144·83
59	6	19926	20799	21235	21671	22108	22544	145·44
59	9	20083	20959	21397	21835	22274	22712	146·06
60	0	20240	21120	21560	22000	22440	22880	146·67
60	3	20398	21282	21723	22165	22607	23049	147·28
60	6	20557	21444	21888	22331	22775	23219	147·89
60	9	20716	21607	22052	22498	22943	23389	148·50
61	0	20876	21770	22218	22665	23112	23560	149·11
61	3	21036	21934	22383	22833	23282	23731	149·72
61	6	21197	22099	22550	23001	23452	23903	150·33
61	9	21359	22264	22717	23170	23623	24076	150·94
62	0	21521	22430	22885	23340	23794	24249	151·55
62	3	21684	22597	23053	23510	23966	24423	152·17
62	6	21847	22764	23222	23681	24139	24597	152·78
62	9	22011	22932	23392	23852	24312	24772	153·39

BATTER OF SLOPES 2 TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet	24 feet	27 feet	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
63	0	22176	23100	23562	24024	24486	24948	154·
63	3	22341	23269	23733	24197	24660	25124	154·61
63	6	22507	23439	23904	24370	24836	25301	155·22
63	9	22674	23609	24076	24544	25011	25479	155·83
64	0	22841	23780	24249	24718	25188	25657	156·44
64	3	23009	23951	24422	24893	25365	25836	157·06
64	6	23177	24123	24596	25069	25542	26015	157·67
64	9	23346	24296	24770	25245	25720	26195	158·28
65	0	23516	24469	24946	25422	25899	26376	158·89
65	3	23686	24643	25121	25600	26078	26557	159·50
65	6	23857	24817	25298	25778	26258	26739	160·11
65	9	24028	24992	25474	25957	26439	26921	160·72
66	0	24200	25168	25652	26136	26620	27104	161·33
66	3	24373	25344	25830	26316	26802	27288	161·94
66	6	24546	25521	26009	26497	26984	27472	162·55
66	9	24720	25699	26188	26678	27167	27657	163·17
67	0	24894	25877	26368	26860	27351	27842	163·78
67	3	25069	26056	26549	27042	27535	28028	164·39
67	6	25245	26235	26730	27225	27720	28215	165·
67	9	25421	26415	26912	27409	27905	28402	165·61
68	0	25598	26596	27094	27593	28092	28590	166·22
68	3	25776	26777	27277	27778	28278	28779	166·83
68	6	25954	26959	27461	27963	28466	28968	167·44
68	9	26133	27141	27645	28149	28654	29158	168·06
69	0	26312	27324	27830	28336	28842	29348	168·67
69	3	26492	27508	28015	28523	29031	29539	169·28
69	6	26673	27692	28202	28711	29221	29731	169·89
69	9	26854	27877	28388	28900	29411	29923	170·50

Batter of Slopes 2 to 1.

Depths of Cutting		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
70	0	27036	28062	28576	29089	29602	30116	171·11
70	3	27218	28248	28763	29279	29794	30309	171·72
70	6	27401	28435	28952	29469	29986	30503	172·33
70	9	27585	28622	29141	29660	30179	30698	172·94
71	0	27769	28810	29331	29851	30372	30893	173·55
71	3	27954	28999	29521	30044	30566	31089	174·17
71	6	28139	29188	29712	30237	30761	31285	174·78
71	9	28325	29378	29904	30430	30956	31482	175·39
72	0	28512	29568	30096	30624	31152	31680	176·
72	3	28699	29759	30289	30819	31349	31878	176·61
72	6	28887	29951	30482	31014	31546	32077	177·22
72	9	29076	30143	30676	31210	31743	32277	177·83
73	0	29265	30336	30871	31406	31942	32477	178·44
73	3	29455	30529	31066	31603	32141	32678	179·06
73	6	29645	30723	31262	31801	32340	32879	179·67
73	9	29836	30918	31459	31999	32540	33081	180·28
74	0	30028	31113	31656	32198	32741	33284	180·89
74	3	30220	31309	31853	32398	32942	33487	181·50
74	6	30413	31505	32052	32598	33144	33691	182·11
74	9	30606	31702	32250	32799	33347	33895	182·72
75	0	30800	31900	32450	33000	33550	34100	183·33
75	3	30995	32098	32650	33202	33754	34306	183·94
75	6	31190	32297	32851	33404	33958	34512	184·55
75	9	31386	32497	33052	33608	34163	34719	185·17
76	0	31582	32697	33254	33812	34369	34926	185·78
76	3	31779	32898	33457	34016	34575	35134	186·39
76	6	31977	33099	33660	34221	34782	35343	187·
76	9	32175	33301	33864	34427	34990	35552	187·61

BATTER OF SLOPES 2 TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
77	0	32374	33504	34068	34633	35198	35762	188·22
77	3	32574	33707	34273	34840	35406	35973	188·83
77	6	32774	33911	34479	35047	35616	36184	189·44
77	9	32975	34115	34685	35255	35826	36396	190·06
78	0	33176	34320	34892	35464	36036	36608	190·67
78	3	33378	34526	35100	35673	36247	36821	191·28
78	6	33581	34732	35308	35883	36459	37035	191·89
78	9	33784	34939	35516	36094	36671	37249	192·50
79	0	33988	35146	35726	36305	36884	37464	193·11
79	3	34192	35354	35935	36517	37098	37679	193·72
79	6	34397	35563	36146	36729	37312	37895	194·33
79	9	34603	35772	36357	36942	37527	38112	194·94
80	0	34809	35982	36569	37155	37742	38329	195·55
80	3	35016	36193	36781	37370	37958	38547	196·17
80	6	35223	36404	36994	37585	38175	38765	196·78
80	9	35431	36616	37208	37800	38392	38984	197·39
81	0	35640	36828	37422	38016	38610	39204	198·
81	3	35849	37041	37637	38233	38829	39424	198·61
81	6	36059	37255	37852	38450	39048	39645	199·22
81	9	36270	37469	38068	38668	39267	39867	199·83
82	0	36481	37684	38285	38886	39488	40089	200·44
82	3	36693	37899	38502	39105	39709	40312	201·06
82	6	36905	38115	38720	39325	39930	40535	201·67
82	9	37118	38332	38939	39545	40152	40759	202·28
83	0	37332	38549	39158	39766	40375	40984	202·89
83	3	37546	38767	39377	39988	40598	41209	203·50
83	6	37761	38985	39598	40210	40822	41435	204·11
83	9	37976	39204	39818	40433	41047	41661	204·72

Batter of Slopes 2 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
84	0	38192	39424	40040	40656	41272	41888	205·33
84	3	38409	39644	40262	40880	41498	42116	205·94
84	6	38626	39865	40485	41104	41724	42344	206·55
84	9	38844	40087	40708	41330	41951	42573	207·17
85	0	39062	40309	40932	41556	42179	42802	207·78
85	3	39281	40532	41157	41782	42407	43032	208·39
85	6	39501	40755	41382	42009	42636	43263	209
85	9	39721	40979	41608	42237	42866	43494	209·61
86	0	39942	41204	41834	42465	43096	43726	210·22
86	3	40164	41429	42061	42694	43326	43959	210·83
86	6	40386	41655	42289	42923	43558	44192	211·44
86	9	40609	41881	42517	43153	43790	44426	212·06
87	0	40832	42108	42746	43384	44022	44660	212·67
87	3	41056	42336	42976	43615	44255	44895	213·28
87	6	41281	42564	43206	43847	44489	45131	213·89
87	9	41506	42793	43436	44080	44723	45367	214·50
88	0	41732	43022	43668	44313	44958	45604	215·11
88	3	41958	43252	43899	44547	45194	45841	215·72
88	6	42185	43483	44132	44781	45430	46079	216·33
88	9	42413	43714	44365	45016	45667	46318	216·94
89	0	42641	43946	44599	45251	45904	46557	217·55
89	3	42870	44179	44833	45488	46142	46797	218·17
89	6	43099	44412	45068	45725	46381	47037	218·78
89	9	43329	44646	45304	45962	46620	47278	219·39
90	0	43560	44880	45540	46200	46860	47520	220·
90	3	43791	45115	45777	46439	47101	47762	220·61
90	6	44023	45351	46014	46678	47342	48005	221·22
90	9	44256	45587	46252	46918	47583	48249	221·83

BATTER OF SLOPES 2 TO 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
91	0	44489	45824	46491	47158	47826	48493	222·44
91	3	44723	46061	46730	47399	48069	48738	223·06
91	6	44957	46299	46970	47641	48312	48983	223·67
91	9	45192	46538	47211	47883	48556	49229	224·28
92	0	45428	46777	47452	48126	48801	49476	224·89
92	3	45664	47017	47693	48370	49046	49723	225·50
92	6	45901	47257	47936	48614	49292	49971	226·11
92	9	46138	47498	48178	48859	49539	50219	226·72
93	0	46376	47740	48422	49104	49786	50468	227·33
93	3	46615	47982	48666	49350	50034	50718	227·94
93	6	46854	48225	48911	49596	50282	50968	228·55
93	9	47094	48469	49156	49844	50531	51219	229·17
94	0	47334	48713	49402	50092	50781	51470	229·78
94	3	47575	48958	49649	50340	51031	51722	230·39
94	6	47817	49203	49896	50589	51282	51975	231·
94	9	48059	49449	50144	50839	51534	52228	231·61
95	0	48302	49696	50392	51089	51786	52482	232·22
95	3	48546	49943	50641	51340	52038	52737	232·83
95	6	48790	50191	50891	51591	52292	52992	233·44
95	9	49035	50439	51141	51843	52546	53248	234·06
96	0	49280	50688	51392	52096	52800	53504	234·67
96	3	49526	50938	51644	52349	53055	53761	235·28
96	6	49773	51188	51896	52603	53311	54019	235·89
96	9	50020	51439	52148	52858	53567	54277	236·50
97	0	50268	51690	52402	53113	53824	54536	237·11
97	3	50516	51942	52655	53369	54082	54795	237·72
97	6	50765	52195	52910	53625	54340	55055	238·33
97	9	51015	52448	53165	53882	54599	55316	238·94

Batter of Slopes 2 to 1.

Depths of Cutting.		Breadths at Formation-Level.						One Central Foot in breadth.
		18 feet.	24 feet.	27 feet.	30 feet.	33 feet.	36 feet.	
Ft.	in.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yards.
98	0	51265	52702	53421	54139	54858	55577	239·55
98	3	51516	52957	53677	54398	55118	55839	240·17
98	6	51767	53212	53934	54657	55379	56101	240·78
98	9	52019	53468	54192	54916	55640	56364	241·39
99	0	52272	53724	54450	55176	55902	56628	242·
99	3	52525	53981	54709	55437	56165	56892	242·61
99	6	52779	54239	54968	55698	56428	57157	243·22
99	9	53034	54497	55228	55960	56691	57423	243·83
100	0	53289	54756	55489	56222	56956	57689	244·44
100	3	53545	55015	55750	56485	57221	57956	245·06
100	6	53801	55275	56012	56749	57486	58223	245·67
100	9	54058	55536	56275	57013	57752	58491	246·28
101	0	54316	55797	56538	57278	58019	58760	246·89

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